PROCEEDINGS

OF

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

PITTSBURG, PA.

VOL. XI.

1895.

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PAGE.

* Indicate pages in the February number.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

FIFTEENTH ANNUAL MEETING.

ALLEGHENY, PA., January 17, 1895.

The fifteenth annual meeting of the Engineers' Society was held on the evening of the above date in the lecture room of the Carnegie Library Building, Allegheny, Pa., President Davis in the chair and 31 members present.

The minutes of the last annual meeting were read and approved.

The reports of the following officers and committees were read and approved:

REPORT OF TREASURER.

For the Year ending January 17, 1895.

1894. January 16.

Balance, ...		$63 65

RECEIPTS.

Dues ½ yr. ending Jan., 1893	(1),	$ 2 50	
" " " 1894	(44),	308 00	
" " " "	(8),	40 00	
½ " " " "	(1),	3 50	
" " " 1895	(283),	1,981 00	
" " " "	(on ac.),	4 00	
" " " "	(46),	230 00	
½ " " " "	(2),	7 00	
½ " " " "	(1),	2 50	
Initiation fees, . .	(20),	100 00	
" " . .	(on ac.),	1 00	
Total from dues, . . .			$2,679 50

From sale of Proceedings, . .	$ 52 88	
" " Buttons . .	9 00	
" advertising in Proceedings,	100 00	
Total from sales and contracts, .		$161 88
Transfers and Refunding,		
Balance World's Fair fund .	$ 37 04	
Refunded by Chicago committee,	65 00	
Pro-rata share of unexpended .		
Balance, ...		
Refunded by Academy of Science and Art, and Associated Societies for share in Janitor's wages, .	40 65	
Total, ...		$142 69
Special contributions,		
To Library, ...	3 00	
For binding, from balance in hands of Reception Com. for entertainment of French Engineers,	9 81	
Total, ...		$ 12 81
Unexpended balance of special appropriation for postage on Proceedings, ...		2 65
Total, receipts and balance, .		$3,063 18

EXPENDITURES.

Printing and binding, . . .	$1,388 50
Salaries, ...	537 50
Office expenses, ...	301 08
Periodicals, ...	157 85
Rent, ...	150 00
Care of rooms, ...	79 36

Stenographic reports,	78 25	
Typewriter cabinet,	20 00	
New books,	15 00	
Telephone,	10 50	
Total,		$2,738 04
Balance,		325 14
		$3,063 18

Respectfully submitted,

A. E. Frost,
Treasurer.

Allegheny, Pa., Jan. 17, 1895.

REPORT OF THE SECRETARY.

Mr. President and Members of the Engineers' Society of Western Pennsylvania:

Our membership corrected to the date of our last annual meeting, January 16, 1894, was	447
There were elected to membership during the year thirty (30), of these twenty-three were matriculated,	23
Making an aggregate of	470
There were thirty-three (33) resignations and seven (7) deaths,	40
Total membership to date,	430

At the annual meeting the officers for the year were elected, full reports from the various committees were presented, and the retiring President delivered his address. At each succeeding meeting some paper was read on an interesting subject, evoking oftentimes animated discussion among the

members present. These reports and papers have been bound in numbers corresponding to the months in which they were presented, and will shortly appear in one book as Vol. X, or Proceedings for 1894.

On October 19 the Postmaster of Allegheny presented us with a "certificate of entry" of our publication as second-class mail matter, thereby lessening very considerably the cost of transmitting the Proceedings of the Society to its members.

Our meetings have been well attended, our transactions issued with regularity, our bills paid promptly; we have money in the treasury, and though our membership has suffered some by the exceptional ravages of the "Grim Reaper," and the financial stress through which the country has so recently passed, we may, I think, congratulate ourselves that the papers presented have been very creditable, and judging from numerous requests for our Proceedings from various parts of the country and abroad, the high rank hitherto assigned us among associations of a similar character has been fully maintained.

Respectfully submitted,

DANIEL CARHART,

Secretary.

REPORT OF LIBRARY COMMITTEE FOR 1894.

There have been added to the library during the year new books, as follows:

By Purchase,	5 vols.
" Donation,	22 "
" Exchange,	11 "
Total,	38 vols.

There has also been added by binding of periodicals 70 volumes, making a grand total of additions to library of 108 volumes.

F. C. PHILLIPS, *Chairman.*

REPORT OF COMMITTEE ON ROOMS.

As you are all aware, we had to give up our comfortable quarters in the Thaw Mansion on the 1st of last April, the Young Women's Christian Association having gotten the better of us in regard to the lease.

The Trustees of the Carnegie Library in Allegheny came to the relief not only of ourselves, but of our sister societies who were fellow tenants with us in the former quarters, and kindly offered us the rooms which we now have free of cost.

The only addition to our furniture during the year has been a desk for use of the Secretary's assistant.

THOMAS H. JOHNSON,
Chairman.

BOARD OF DIRECTION.

The Secretary presented the report of the Board of Direction, in which it was recommended that the names of certain delinquent members be stricken from the roll, and upon motion this recommendation was concurred in.

Mr. G. H. Davison presented the report of the Sanitation Committee, which upon motion was accepted and the committee continued.

The report of the Auditing Committee, H. J. Lewis, Chairman, was accepted.

The retiring President then read his address.

PRESIDENT'S ANNUAL ADDRESS.

One of my predecessors, Mr. E. B. Taylor, in the presentation of an address before the Society, January, 1887, stated that the year which had just closed was one of the most prosperous ever known in the history of Pittsburgh, and the prosperity was general throughout the United States, but at

the same time it was distinguished by gigantic labor combinations, strikes and riots. With the year just closed we have experienced a period of the greatest commercial depression, supplemented by the same conditions as to strikes and riots, with the addition of the agitations connected with the revision of the tariff, and proposed reform of the currency.

All business was greatly restricted, want and suffering were present everywhere, with great increase in crime, all resulting from the prevailing depression.

On the other hand there were and are compensations, though probably not very evident, among which I may mention: the checking of wastefulness in different quarters; bringing to light defects in the organization and management of many of our industries; calling attention to defects in the laws relating to our currency, and in developing new trains of thought and action.

Social questions have been brought to the front; matters relating to public health have received considerable attention; such as the proper housing of the tenement population; and the securing of better sanitation in cities and towns.

TRANSPORTATION.

The mileage of steam railroads built during the year, according to reliable report, did not reach 2,000 miles. As this work is usually taken as an index of the demand for engineering work, it is easily seen that the past year has been an unfavorable one for the profession, and that the field does not look very promising for the coming year.

There are developments, however, in other quarters that give a more encouraging outlook.

The low prices for labor and materials prevailing are favorable for building enterprises, and for carrying out needed municipal and other work.

While construction of steam railroads has lagged somewhat, there has been unusual activity in building short line electric and traction roads for town and suburban service. We have several important electric lines, as well as cable traction roads. We have, in Allegheny county, 248 miles of electric road in operation, and 35 miles projected, and also 27 miles of cable traction road built, making an aggregate of 275 miles of completed lines.

"There are in the country," according to a statement in the January number of the *Review of Reviews*, "in round numbers about 10,000 miles of electric road, and 20,000 electric cars in present use; and it further states, that the greatest improvements are being made in the equipment, and that the Westinghouse Electric Company (a home industry, by the way), has introduced a new motor of great efficiency."

According to the same authority, "the most revolutionizing change in the electric railway field this year, has been the increased use of generators directly connected."

"The largest railway power plants are being supplied with them."

"One company has this year built and established 30,900 horse power of these generators and is building 20,000 horse power more."

It is very evident that there is a good field for the employment of properly qualified engineers in this direction. This branch is just in its infancy, and it is prophesied that in course of time, by gradual progress, these lines will extend for longer and longer distances until they reach from city to city, and compete with the steam railway lines. One New England railway manager has already voiced his apprehensions in this matter; though generally these roads are not considered as rivals of the railroads but are considered rather as feeders.

There has just lately been let a contract for a section of some 15 miles of electric road, which is to extend from Baltimore to Washington, a distance of 50 miles.

An Ohio legislator is formulating a bill to be presented to the incoming Assembly to authorize the construction of these lines on all the leading thoroughfares of the State, at the expense of the State in part, in the same manner as State canals were formerly constructed.

The development of electric railways is rapidly changing the condition of rural life, giving it the advantage of city life; and is extending the towns beyond their otherwise natural boundaries. In this way these lines promise to increase the comforts of the laboring classes, by enabling them to secure homes for themselves in the country.

MUNICIPAL ENGINEERING.

In local affairs there is a great deal of municipal work, in the way of paving and sewer building going on in both cities. In Pittsburgh this is most noticable in the East End district.

In Allegheny the streets in the center of the city are being improved; and two large trunk sewers are under construction, one 12 feet in diameter, at Woods Run in the west end, and the other, 8½ feet in diameter, on Madison avenue and East street, in the east end of the city. Commendable efforts are being made to extend the street improvement into the suburbs.

Allegheny possesses natural advantages not equaled or excelled in any of our inland cities, in the lay of its suburban territory, overlooking the Allegheny and Ohio rivers, and in its broad streets and open spaces in the old part, which are not usually found in manufacturing places.

Some of the street and sewer work recently completed or now in progress, was projected nearly two decades ago, all of which tends to show that the municipality is very conservative.

WATER SUPPLY.

The water supply of both Allegheny and Pittsburgh is unsatisfactory. The source, in each case, is within the sewage

influence of the cities and the plants inadequate for the service. Both cities are committed to a heavy expenditure for the extension of these works.

In the meantime private water companies are building extensive water works, notably the Monongahela Water Co., and the St. Clair Water Co., both drawing their supply from the Monongahela river, within or near the city limits, to supply large areas of the city and surrounding territory.

The Allegheny river is the only source affording an inexhaustible supply of soft, pure water: and the nearest point from which it can be safely drawn is at Huling's Eddy, opposite Hulton station, on the A. V. R. R. This point is above Verona and the mouth of Plum creek. The water there has a depth of 19½ feet, at low water, and the place is favorable in other respects for pumping works, with desirable locations in the vicinity for reservoirs.

The pollution in the river above Huling's Eddy is not considerable, and it will be many decades before the population here approaches that on the banks of the Schuylkill river from which Philadelphia draws her supply.

The population in the Allegheny basin is about 56 per square mile. In the Schuylkill valley it is 166 per square mile. In the Thames valley above Thames Ditton, it is 250 per square mile.

The flow of water in the Allegheny river, at low water stage, exceeds that of the Schuylkill at least five times, so that the pollution at its worst on the Allegheny must be in greatly diluted form, as compared with the Schuylkill. For domestic use and for manufacturing, river water will be preferable to water taken from mountain sources in this mining region (even if the supply could be made adequate by resorting to extensive storage, which is doubtful) on account of the volume of the impurities, as compared with the discharge of the streams during low water. The streams supplying Altoona and Johns-

town furnish examples of the sources and extent of contamination to which the smaller streams may be exposed.

What is required in our new pumping works is ample storage capacity for settling the water after floods and for removing at all times, the heavier impurities from it. With such provision other means of purification can be put off for a long time.

State Legislation is now proposed to protect the streams from unnecessary and injurious pollution.

The recent investigations of the city water supply, made by a committee composed, in part, of members of our Society, contained in a joint report published under the auspices of the Chamber of Commerce, furnished valuable and exhaustive information on this subject.

ROADS.

The Governor in a recent message to the Legislature took occasion to urge the necessity of making laws to improve the condition of the public roads in the State.

This subject has now been before the public and the Legislature for a long time, and is still one of the live questions of the day. Since the work of your committee on this subject was given to the public, about four years ago, the Association of American Wheelmen have been unceasingly active in keeping the subject of better roads constantly before the people, and now even the United States Government, through its Department of Agriculture, has taken the subject under its fostering care.

I regret to observe, however, that most of these efforts are frittered away in attempts to teach the public how to make good roads, instead of devising ways and means. The literature on the theory and practice of road making is ample. There are plenty of competent, well-qualified engineers willing to do the work if the proper legislative machinery is provided.

We notice the Governor's suggestion to the Legislature on

this topic, is in line, in the main, with the recommendations for the improvement of roads made by this Society, through the report of its committee before referred to; the salient features of which are given on the first cover page of the Society's pamphlet, and need not be repeated here.

It might be well to mention here, that this report has been used to some purpose in framing road laws, outside of Pennsylvania, and that its facts and figures were freely incorporated, and without credit being given to this Society, in the book entitled, "A Move for Better Roads," published in Philadelphia in 1891. (See pages 245 and 276).

During the past year a road commission appointed by Governor McKinley, of Ohio, made a report on the road question, in which is given some interesting data on transportation: They have ascertained the relative distances to which a ton of freight can be transported by the different means in use, for equal cost, as follows:

Horse power,	5	miles transportat'n,	per ton		$1.25
Electric,	25	"	"	"	1.25
Steam cars,	250	"	"	"	1.25
Steamships on the Lakes,	1,000	"	"	"	1.25

They also published a diagram presenting the foregoing facts in graphic form, and which is here reproduced.

"The inner circle, which is a mere dot, has a radius of five miles, and the average cost of carrying a ton five miles with horses (which is the most expensive of any power in use) is $1.25, being 25 cents per ton per mile. The second circle and the next largest one has a radius of 25 miles and represents the distance which a ton can be carried without additional cost, by substituting electric cars for horses and wagons. This is estimated at five cents per ton per mile. The third circle represents the distance covered by steam cars, the radius of the circle being 250 miles. The average cost per ton per mile being only five mills.

"The outer circle has a radius of 1,000 miles, and represents the distance which can be reached by the steamships upon our lakes, without additional cost, that is to say, the average rate of transportation per ton per mile is $1\frac{1}{4}$ mills, which makes for 1,000 miles \$1.25, the same as the cost for carrying a ton five miles with horses.

"In other words, by applying electricity, we can carry at the same cost five times as far as with horses.

"By applying steam to cars, we can carry fifty times as far as with horses, and by applying steamships to deep water we can carry 200 times as far as we can with horses, and all at the same cost.

"No matter how much may have been expended for these various means of transportation—whether of public money or private money—their value ceases as soon as a better means of transportation is brought into existence. That the steam cars and electric cars are both better means than horse power, so far as they can be applied, is apparent to any observer. There can be no doubt that the building of steam roads has been a mighty and controlling influence in massing the population, and has cheapened transportation to such a low point as to carry a ton fifty times as far as can be carried by horse power, at the same cost."

While urging the importance of the improvement of our public highways we should be careful that we do not furnish at the public expense a free road bed for the electric railways.

Allegheny county has, in round numbers, 1,800 miles of roads, good, bad and indifferent, mostly bad. Only 75 miles of the total are macadamized; 33 miles are plank roads.

A portion of the macadamized roads and all the plank roads are toll roads, owned by corporations; all others are maintained by the several townships.

It is estimated that about \$110,000 is expended in the county annually for maintaining township roads.

Most of the road bridges outside of the cities are county bridges; there are in all 194 bridges—158 iron, 21 stone arch and 15 wooden bridges.

The combined length of iron bridge superstructures is one and seven-tenths miles.

The total cost of stone and iron bridges is approximately $660,000.

All the later iron bridges of spans from 30 to 65 feet, are plate-girders. There are 80 of these.

Bridges of late years are built heavier than the average highway structures, being designed under rigid specifications and constructed under careful inspection.

The annual cost of maintaining the county bridges is about $10,000.

Some of the iron bridges first erected were too light for the present traffic, and owing to the thin plates and closed sections of the earlier designs, these bridges readily succumbed to the effects of rust, and have lately been replaced with heavier structures.

Seven such bridges still remain to be rebuilt.

The improvement in the bridges here is having a beneficial effect in the counties adjoining. Already in some of these counties bridges have been erected conforming to the specifications in use here, showing how a good example will beget improvement in other localities.

MISCELLANEOUS ENGINEERING.

Several important works lately accomplished through the skill of Pittsburgh engineers are worthy of notice.

The steel plant of the Ohio Steel Company at Youngstown, just finished, one of the largest and most complete establishments of its kind in the country, was designed by Mr. Julian Kennedy, a member of our Board of Direction.

The buildings of the Pittsburgh Electric Manufacturing Company, East Pittsburgh, covering some 9 acres, and with

accommodation for 3,000 workmen, were designed by a fellow member, Mr. Thos. Rodd.

In the bridge building line, one of the most notable of the 17 bridges spanning the rivers at this place, though not the latest achievement, yet of recent date, is the Ohio River Connecting bridge, below the city, about ⅘ of a mile in length—the bridge proper having a length of 3,252 feet, and the viaduct approach on the north side of river 1,298 feet—with a channel span of 523 feet, placed at an elevation of 80 feet above low water. This span was built on high staging placed near the shore below the bridge site, and then floated bodily, on 9 barges, to place, and lowered on the piers without interrupting navigation. The credit for this method of erection is due to Mr. C. L. Strobel, a member of the Engineers' Society.

The cost of this structure was $602,000, divided as follows: $545,300 for bridge proper and $56,700 for viaduct.

This bridge affords the first instance of the use of pneumatic foundations in this vicinity: which, together with the novel mode of erection, seems to justify our giving it at least some notice in our publications. It is to be regretted that no paper has been presented to our Society describing it.

This bridge was built under the direction of Mr. M. J. Becker, Past President of this Society. It is of direct benefit to Pittsburgh by facilitating the transfer of freight through and in the city.

Another noteworthy structure which has not been mentioned in our proceedings, is the Sixth Street Bridge, over the Allegheny river, designed by Mr. Theodore Cooper, a former Pittsburgher. This work was carried to a successful conclusion under the supervision of our fellow members, Messrs. Wilkins and Davison.

It consists of two spans of 445 feet each, carrying a roadway 40 feet in width, and two sidewalks, each 10 feet. The cost of the work was $560,000.

The structure replaces the beautiful Suspension bridge

erected by the late John A. Roebling in 1859, which had to give way to the growing demand for rapid transit.

The electric generators now being furnished for the Niagara Power plant by the Westinghouse Electric Co., are the product of Pittsburgh engineering talent, and the work largely of engineers connected with this Society.

The experimental work connected with the investigations of the Aeroplane, by Prof. Langley, by which great advance has been made toward the accomplishment of ærial navigation, was made almost in sight of this building, and when later experiments at Quantico shall have made the air ship a success, Allegheny may claim a share in the glory.

The project of a ship canal from Pittsburgh to Lake Erie, inaugurated and planned by Pittsburgh business men and engineers, bids fair to be realized in the near future, and when built will greatly increase our facilities for transportation.

The effective presentation to the public of the engineering features of the scheme is largely due to the efforts of Colonel T. P. Roberts and Mr. W. Lucien Scaife, Past Presidents of this Society.

The outlook in the Connellsville coke region is encouraging. The production for the last week in the year was reported as reaching 150,000 tons, and the shipments made to consuming points for the same time amounted to over 8,200 cars. The development of this business in the near future will no doubt lead to the use of improved furnaces by which the bye-products which now go to waste will be saved, thus enlarging the field of work for our chemical section.

The structural engineer has already found a new field of energy in the erection of steel shaft head frames, coal tipples and mine buildings which are now being substituted throughout the coal region for the old style wooden structures. The successful introduction of this change is chiefly due to the members of this Society.

In connection with this subject, it seems but proper to

mention the tragic death of our fellow member, Mr. J. H. Paddock, Chief Engineer of the Frick Coke Co., in the riot in the coke regions last summer.

He was sacrificed to that spirit of lawlessness pervading the country and which led up to and had its climax in the riots later in Chicago.

Mention must also be made of the deaths of the following members: Mr. R. N. Clark, Past Secretary; Mr. S. M. Wickersham, Past Secretary; Mr. A. Gottlieb, Past President; Mr. James. B. Scott; Mr. Carl Amsler and Mr. Jas. T. Froenheiser.

Appropriate memorial resolutions regarding these deaths will be found in the proceedings.

The Society has also lost warm friends in the deaths of Mr. Campbell B. Herron and Mr. Abram Garrison.

OUR PROSPECTIVE NEEDS.

Pittsburgh, to realize the greatest good from its resources and natural advantages, needs a good deal in the way of local improvements, as well as improvements reaching out to other sections.

The harbor should be properly improved. Something is being done in this line now by the United States Government in building a dam at Herrs Island, to extend the harbor five miles up the Allegheny river to Sharpsburg, but the query is, when will this work be made available.

It is now eight years since the first appropriation was made, and there is no part of the construction yet in view.

This improvement is estimated to cost $600,000, which is not a very large amount, and it would seem that the annual appropriation might be increased so as to hasten the conclusion of the work. It should be mentioned here that originally this dam was designed as a fixed structure, and it was largely through a memorial of this Society that the United States Engineers finally determined to make it an adjustable dam.

Pittsburgh has 20.8 miles of water front on the three rivers, and Allegheny has 6.5 miles on the Ohio and Allegheny

rivers. By completion of the new dam at Herrs Island, all this will be on deep water.

The harbor is being injured for navigation by encroachments, and by the accumulation of waste on the shores and in the bed; and moreover, it is being rendered inadequate to carry off the floods, by reason of the great and irregular contractions made in the cross sections of the water way in many places, greatly increasing the danger to the city.

An examination of the High and Low water plans regulating the boundaries of the rivers here, will show that the contraction of the flood section by filling in beyond the established lines, amounts to, in some cases, as much as 20 per cent.

These encroachments are noticeable on the Monongahela river in the vicinity of Tenth Street bridge, and in the Allegheny at Herrs Island. The encroachments in the Allegheny river are beginning to show an influence on the heights of floods in districts above the city. In the flood of February, 1891, the water was two feet higher at Sharpsburg and at Harmarville (the latter 12 miles from Pittsburgh) than ever before known; though this flood at Pittsburgh was not as high as the flood of 1884, by one foot.

The river regulation here as fixed by the survey authorized by the State in 1858, should be respected, and the boundaries made as near as possible to conform to the lines laid down by that survey, and the banks and slopes made and maintained on these lines.

It is possible, in view of the changes that have been made in late years in the river beds by improvements along their banks, that a revision of the lines would be advantageous. The width of the channel can probably be reduced in many places, but the contraction of the stream must be made uniform; the regulation must be done with system, and the banks must be built and maintained so as to secure a continuous uniform section for the stream. At many points the river line monuments are lost or buried, or have been disturbed by im-

provements. These should be re-established either upon the old lines or upon lines newly established.

I am aware that corporations and individuals who have encroached on the rivers, will not look with favor on restraints in this respect, but such facts as the above should satisfy them that their own interests require this obstruction to stop, otherwise future floods may do incalculable damage to their property and to the city at large.

The United States Government, I understand, is engaged in making survey for fixing high and low water lines for the purpose of navigation in this vicinity, but boundaries or limits so fixed would not take the place of nor invalidate the lines formerly established by the State, and which by law determine the boundaries of property abutting on the rivers.

What is greatly needed is to have some one charged with the duty of seeing that these lines, whether those established in 1858, or others to be fixed, are adhered to, and that farther encroaching on the channel of the rivers, as defined by these lines, is forbidden.

The entire river front, as before defined, should be improved with better wharves with railroad facilities contiguous thereto, for the better accommodation of manufacturers, and exchange of water and rail freight.

Such an improvement of the river front would make desirable manufacturing sites out of many properties not now available for such purposes.

There is also great need for larger and better terminal railroad facilities. Taking into account the volume of business handled here we are, in this respect, very poorly accommodated as compared with our sister city in the East.

In the matter of grade crossings our two cities have fewer than many other large places, but those which we do have are a serious obstruction to city traffic, and a constant source of danger and delay. They should be eliminated as soon as possible ; and in connection therewith the removal of the railroad

track from Liberty street, one of our main thoroughfares, should be accomplished.

Of late there seems to be a tendency for large industries to seek locations away from Pittsburgh. Many of our glass works have left us for the gas field of Indiana.

An extensive new steel plant has just been completed at Youngstown, and another is now in course of erection on the shore of Lake Erie, at Lorain.

If we wish to hold our position as the leading center of heavy manufacturing industries, we must increase our facilities in every possible way.

Another matter in the way of needs should be mentioned: There is no reliable map of Allegheny County, and hardly a week passes that inquiry is not made for such a map.

The best large map in use is one published originally in 1884, by Mr. Otto Krebs, our fellow townsman, and reissued by him in 1890, but it is not up to date.

The United States Coast and Geodetic Survey, a system of triangulation for determining accurately points on the surface of the earth, should be extended to this part of the State, and the skeleton thus obtained could be filled in with complete topography, thus affording correct and reliable maps. These would be of great value to engineers and to capitalists contemplating the development of mines, roads and other enterprises. New York and New Jersey are far ahead of us in this respect.

Considerable work in this direction has been done in the eastern and southern part of the State during the last decade, but the western part has been wholly neglected.

The work, so far as done, was for the most part under the immediate supervision of a civil engineer connected with one of the leading Universities. We have in like manner a competent engineer or official in our University, who could extend the work in this section, so that it might ultimately reach the north-

ern boundary of the State and there connect with the triangulation already accomplished along the lakes.

In accordance with a resolution passed by our Society in 1893, the Metric system of measurement has been introduced, and has been put into practical effect in the reading of one or two papers.

It should be mentioned that within the year just passed the United States Government, through the good offices of a Western Pennsylvania Congressman, Hon. Chas. W. Stone, a member of the Committee on Coinage, Weights and Measures, has adopted for standard units of electrical measurement the Metric system.

The papers presented in both Engineering and Chemical sections during the year were not voluminous, but will compare favorably with those of other years in point of general interest, as shown by the reception given them by the leading journals and by the discussions of the same by prominent men not members of our Society.

Mr. Charles F. Scott's paper on "Systems of Electrical Distribution," was of a high order of merit, and is a valuable addition to electrical literature.

The series of papers on waste in fuels, forming as it does, a connected treatise on the several sources of loss in fuels, is of great practical use and interest to all consumers of coal.

Mr. Thomas Johnson's paper, "The Theory of Dynamic Work Applied to Static Forces," while his conclusions have not been generally accepted, has neverthless set educators and others to thinking in new channels concerning some elementary subjects.

The paper on "Gold Milling," by our late lamented Secretary, Mr. R. N. Clark, is a clear, concise and comprehensive treatment of the subject which redounds to the honor of its author and to the credit of the Society. It has attracted the attention of mining experts, both at home and abroad.

It is to be hoped that the coming year will give us a class

of papers of still higher standard and greater volume, and carry this Society into the first rank of sister associations, as the subjects are numerous and important and the ability to handle them is not wanting among our members.

The election of officers being next in order, Messrs. Diescher and A. D. Wilkins were appointed tellers, and reported the vote unanimous for the following candidates:

For President, one year, Thomas H. Johnson; for Vice-President, two years, Emil Swensson; for Directors, two years, Harry J. Lewis and Karl F. Stahl; for Treasurer, one year, A. E. Frost; for Secretary, one year, Daniel Carhart; whereupon the President declared them duly elected.

Mr. T. P. Roberts here moved that a committee be appointed to escort the newly elected President to the chair, which motion was seconded and carried, and Messrs. Roberts and Swensson were appointed the committee to perform this duty. Mr. Johnson was then escorted to his seat and Mr. Davis retired.

It was then voted that the annual meeting adjourn.

Daniel Carhart,
Secretary.

January 17, 1895.

The regular monthly meeting of the Society was then held, Mr. Johnson in the chair, and 31 members present.

The minutes of the last regular meeting were read and approved.

The Secretary read the names of two applicants for membership, passed by the Board, and to be voted on at the next meeting.

The names of Alexander M. Gow and Henry W. Fisher were then brought up for ballot, Messrs. Davison and Camp being appointed as tellers.

Thirty votes having been cast for each candidate they were declared duly elected to membership.

It was moved and seconded that the Board of Direction of the Society be instructed to consider the advisability of securing rooms conveniently located in the business portion of Pittsburgh, either by purchase or rental, and to report to the Society at their earliest convenience, not later than the next regular meeting. Carried.

Here followed quite an extended discussion as to the advisability of accepting rooms in the library building in Schenley Park, the general idea being that it would be better to secure rooms in a more convenient location in Pittsburgh.

Mr. T. P. Roberts asked that a committee be appointed to draft resolutions on the death of Mr. J. D. McCune. The chair appointed as this committee Messrs. Roberts, Carhart and Diescher.

It was voted that the committee representing the Society on the Sanitation Committee be continued.

Adjourned.

Daniel Carhart,
Secretary.

CHEMICAL SECTION—THIRD ANNUAL MEETING.

Allegheny, Pa., January 18, 1895.

The Third Annual Meeting of the Chemical Section was held in the Lecture Room of the Carnegie Library Building on Friday evening, the above date.

Mr. W. E. Koch, Chairman; A. D. Wilkins, Secretary.

The Minutes of the Second Annual Meeting were read and approved.

The Secretary reported for the year 1894 as follows:

The past year has not been as encouraging as the first two

years, the average attendance at the meetings being but 10 members, and on two regular meeting nights (June and October) there were less than a quorum present.

Mr. A. T. Eastwick, elected Secretary in January, resigned in April, having left Pittsburgh for the eastern part of the State.

There were six papers read during the year. One of these, "Gold Milling," by R. N. Clark, has received favorable notice from the engineering and mining journals. Prof. Phillips' paper on "Hydrogen Peroxide," will bring that reagent to the notice of our members.

The Chemical Section's Committee on Water Supply contributed a valuable paper on that subject for the Report of the Joint Commission on Water Supply. The above committee is now a part of the Sanitary Committee of Pittsburgh.

The Committee on Chemical Literature made reports at each meeting.

There are at present 76 chemists who are members of the Engineers' Society.

We have lost by death two members: Mr. R. N. Clark, of Pittsburgh, and Mr. Jas. J. Froenheiser, of Johnstown, Pa. Memorials of these members were reported and printed in the transactions.

Approved by vote of meeting.

The Committee on Chemical Literature reported verbally as follows:

The members of the Committee on Chemical Literature have read during the past year all the chemical literature accessible to them, and have reported monthly to the Society all matters of interest connected with chemistry.

It is very important that this Committee make regular monthly reports to the Society, and that the reports be printed in our transactions, thus forming a valuable index to chemical literature.

The retiring chairman then addressed the Society as follows :—

GENTLEMEN :—I hunted dilligently for a subject for my address, but after a long search I finally decided to take a look backward, and talk to you about the history of a process which is of interest to all chemists and which I was fortunate enough to see through its various stages of evolution. I refer to the Siemens' process of steel making, which from its birth was nursed and nourished by chemists, and I do not believe that any other branch of steel making owes more to the chemist than the open-hearth steel process. One day, back in the '60s, Professor A. W. Williamson, professor of chemistry in University College, London, came into the laboratory and gave me a new steel to analyze ; it was soft and could be cut with a knife, and on analysis seemed to be nearly pure iron free from any intermixture of cinder or slag. That was a new idea of steel to all of us.

Now for the birth-place of this now great industry. In a back yard in Hampton Street, Birmingham, England, stood a small open-hearth furnace of about 2700 lbs. capacity, at the most. The street was narrow and dirty, the yard not very big, possibly about eighty by twenty, and the entrance was through a gateway over which part of the house was built. The chemists in charge were W. Hackney, of the University of London, and Arthur Willis, a pupil and assistant of the celebrated Professor A. W. Hoffman. The late Sir William Siemens, a first-rate chemist and physicist himself, believed in thorough chemical work and careful analysis at every step ; and under his direction all the materials used were carefully analyzed, melted and made into steel, the products analyzed and then hammered or rolled for physical tests. A small steam hammer stood near the furnace and later on a small rotator was added to the experimental plant of the "Sample Steel Works," as it was then called.

The early steel was all made from pig iron and scrap

(Siemens-Martin process) and old iron rails played an important part, so much so, that later on, when the first Siemens Steel Works were established at Landore, South Wales, a large part of their output was exchanging old iron rails for new steel ones,—a modern rendering of the story of Aladdin; the old iron rails were shipped to Landore, and for them and a small consideration the railroad companies received new steel rails, made from their old iron rails and some pig iron in the Siemens Open Hearth furnace. The Landore works were run by the chemists, Messrs. Hackney and Willis. The laboratory would not bear comparison with the splendidly equipped laboratories of these days, but though somewhat rough, it was serviceable, and analyses were done systematically. The late Arthur Willis was chief chemist, and not only made the analyses, but, in the early days, superintended the melting and working of the heats, making analyses as the heat progressed from melting to pouring. His methods of analyses were rapid, and accurate enough for furnace work.

Carbon was determined by the color test even as now; in all these years there has been no change in this test.

Phosphorus was determined by dissolving five grams in nitric acid, and precipitating the phosphorus by a nearly neutral solution of molybdate of ammonia. The exact method was as follows: Five grams of steel drillings were weighed up and put into a marked beaker, then nitric acid of 1.25 specific gravity, in known quantity, was added, and the steel dissolved, and the solution evaporated to a constant bulk in the marked beaker. To the hot solution was added a constant quantity (about equal bulk) of molybdate solution, made as follows: To 50 grams of molybdate of Ammonia dissolved in 50 c. c. of ammonia (.880) was added nitric acid to dead neutrality, and then a drop or two of ammonia to just alkaline; this was diluted to 600 c. c. and filtered. On adding this the phosphorus at once precipitated, and by its bulk it was easy to tell whereabouts the steel was. By constant practice and care it is pos-

sible to become very expert in these quick methods, and they were useful.

The sulphur was determined by dissolving five grams of steel drillings in dilute sulphuric acid—one part acid to four parts water—and passing the gases evolved through a cold saturated solution of cupric sulphate. By always using exactly the same amount of steel, acid and copper solution, in bottles carefully marked, we could tell quickly and approximately what the amount of sulphur was in the steel or pig iron under examination.

Manganese was done by the color test and also by the acetate method. Silicon in the usual way, and copper by comparison in an ammoniacal solution, with a standard blue copper salt in a prism-shaped bottle.

It was by this careful watching of every heat that the late Sir Wm. Siemens and Arthur Willis evolved the Siemens or Ore process; that was a big step in advance; as by it the steel was improved and also the use of scrap was no longer an absolute necessity. Later on mild steel was made by adding iron blooms; made in a Siemens rotator, to a bath of molten pig iron.

As I have said before, every step was preceded by analysis. This extended even to the manufacture of refractory materials; the mixture of Silica with lime for making the Silica bricks was analyzed and corrected, if necessary, before the "batch" was moulded into brick. The sand used in the furnace bottoms was also analyzed. Sir Wm. Siemens was one of a thousand; a first-rate man of science himself, and most prolific in ideas. He believed firmly in systematic chemistry, and preferred to trust to chemists rather than to engineers; as he so often used to say, "What was the use of having the finest machinery in the world, if your steel was not right when it left the furnace?" To this end he insisted on his chemists taking the heat out of the furnace, and until the chemist had passed on the samples of steel and slag, and knew

it was all right, the furnace should not be tapped. He also insisted that heats should be analyzed before rolling. Under such a master, and such a system, it did not take long to bring Siemens Steel to the front.

Twenty-five years ago some iron-masters had primitive notions of chemistry and chemists. One large proprietor of iron-works described a chemist as "a harmless fellow who mixed up messes and made awful stinks"; another came to Landore one day and said he had heard that chemists were needed in a steel-works, and if we could recommend him one he would pay him four dollars a week. Not long after it was discovered that a chemist was as necessary as steam or coal. The history of the Siemens process shows how necessary chemical work is, and how chemistry is the "fons et origo" of all good metallurgy. The chemist should always precede the engineer. Nowadays we seem to be bent on "tonnage" and "machinery." They are good in their way, but the first thing is to make good steel and that is just where the chemist is needed. I like to see the chemist taking out the heats, and his mark should be on all steel before the mechanical departments take hold; this applies to Bessemer as well as Siemens steel.

Chemistry is responsible for all the real improvements in the making of steel, and I think there is a great future for the chemical profession, for there are a vast number of improvements yet to be made. Consider the field open before us; there are more than a dozen elements now used in steels of various kinds; this will give us about five hundred million combinations, surely a wide field, and one that no one but chemists can cover with any chance of success. How little we know of the alloys or combinations of steel. Every day new problems confront us and questions arise that are hard to answer. How often do we say, "Don't know." It is not a scientific answer, but, as we say, "What are you going to do about it?" Work and think. There is another field for us,

"the microscopic field." I don't think chemists use it enough. There is a great deal to be learned there. Take any work on petrology and note how sections of rocks and minerals are treated with chemicals and their effects noted. It seems to me (and I have tried it in a small way myself) that there is a good deal to learn here. When you think over it, it is a brutal way to take a piece of steel and destroy its individuality and identity by acids and heat, and then to say this merely consists of carbon and phosphorus and other bodies; we ought to go a step farther and be able to say which carbon and which phosphorus, etc., it contains. We ought to be able to distinguish chemically and physically between the modifications of the so-called elements, and point out which is harmful and which is harmless. In a long experience of steel making I have seen strange things in steel, and we all know that our present system of chemical analysis often fails completely to explain physical tests and results.

I know this is difficult, but my old teacher, the man who first turned my head towards chemistry, the late Michael Faraday, told us, "You must always look for the thing that is not; the apparent is not always the true cause, the essential is not always the obvious." This is illustrated well by the fact that Faraday's theories on electricity, which have been under a cloud since 1855, are now received by nearly all the scientific men of to-day.

Turning from the consideration of steel, of which probably you have had enough for one evening, let us glance over the advances made by chemists during the past year.

The chemistry of extreme cold in the hands of Professor Dewar is opening up new fields for exploration; the researches of Lord Rayleigh seem to point to a new constituent of the atmosphere, and this leads me to speak of our old friend, nitrogen. I wish some of our chemists would study nitrogen more; sometimes it is a great nuisance; when we try to make gas from coal in a gas producer, we could do with a good deal

less nitrogen, and if we could eliminate most of it our gas would be better. The text books pass nitrogen over very curtly in their earlier pages, calling it an inert gas, but later on we find the same gentleman very active, showing up in dyes, ammonia compounds, explosives, etc., reminding me of the dull boy who turns into a brilliant man. If this work of Lord Rayleigh's will only turn chemists away from the study of unpronouncable compounds of forty syllables and twice-used-up-alphabets of three languages to the simpler but more practically useful study of nitrogen, much good may result.

The electric furnace of Professor Moissau, of Paris, has given us some very interesting studies at high temperatures, and he has obtained some wonderful results. His experiments are worthy of careful attention, especially by metallurgists. If, as we were told here the other night, we can get an annual horse-power for $17 from the Niagara Falls electrical plant, there is a future for the electrical furnace, especially when a horse-power in Pittsburgh from coal and steam is costing from $30 to $50 a year, $50 being nearer the mark.

To show a further field for the chemist, I have not yet seen a blast furnace round Pittsburgh fitted with appliances to save bye-products such as we see in Europe, nor a coke oven built on modern principles. We are ten years behind in our wasteful methods of making coke. Little Belgium can teach us a good deal about coke-making and its profitable bye-products, and Germany a good deal more.

Looking back over thirty-five years I can see a grand change; to-day there are great laboratories, splendidly fitted, scattered broadcast over the land; but in the fifties they were very few and far between and poorly equipped. In those days if you asked for a chemist you were referred to a drug-store, and you could wander from works to works and never find a laboratory. This is all changed, and to-day the chemist is or ought to be the life and soul of the mill and his workshop the best equipped.

To turn our glances on ourselves is the next thing, and here I think there is room for improvement. As a Society we might have done more and I feel that much of the blame rests on me, and I hope that my successor will have more magnetic attraction than I possess. Two papers were read before us this year of which we are justly proud—one on "Gold-Milling," by our lamented friend, Mr. R. N. Clark, and the other on "Hydrogen Peroxide," by Prof. Phillips. We sustained a great loss in the death of Mr. Clark. He did a great deal for this Society and supported it in every way; moreover, he had the enthusiasm which compels success—such men are missed. We also have to lament the death of Mr. J. J. Froenheiser.

I think it a good scheme to begin the new year with the idea of "official analysis." It will take away the indefiniteness of analysis and bring us all closer together; and not only this, but it will bring us into the position we ought to hold. Pittsburgh should be looked up to by all the rest of the world as the great home of the modern manufacture of steel. I think without doubt we have some of the finest mills in the world; we have great natural advantages in the shape of cheap and good fuel, and (in the near future) cheap transportation. Our geographical position is as good as our geological foundation; we have men capable of advancement in every direction, and we have everything that points to a great and increasing iron and steel business, to say nothing of our other great industries such as glass, etc., and I hope that this Society will take the position it ought to take as the leading industrial Chemical Society of the great and growing west.

The Committee on Nomination of Officers for 1895 then reported as follows:

For Chairman, Jas. M. Camp; for Vice-Chairman, Jas. O. Handy; for Secretary, A. D. Wilkins; for Directors, C. E. Stafford and W. E. Koch.

Mr. Handy having resigned from the Society, Mr. K. F. Stahl was nominated for Vice-Chairman.

These officers were duly elected by ballot.

Chairman-elect Jas. M. Camp, was then escorted to the chair and addressed the Society as follows :

GENTLEMEN :—For your kindness in placing me in the chair that has been occupied by such men as my friend Mr. Koch, Prof. Phillips, Dr. Dudley and Prof. Langley, I thank you. It is an honor that any man should be proud of. With the new year beginning to-night, I would like to see more life put into the Society.

This does not entirely depend upon the Chairman. If Fresenius, himself, were Chairman, he could not make a success of this Society, unless the members co-operated with him. It would not be difficult for any member of our society to write a paper on metallurgical chemical matters. The paper need not be long. The most important thing is to excite discussion ; that is one of the most pleasurable features of these meetings, and it is of incalculable benefit. The pleasantest part of the meetings is the discussions: The selection of a man, that you know knows what you want to know, and the getting it out of him.

Adjourned.

A. D. WILKINS,
Secretary Chemical Section.

January 18, 1895.

The regular monthly meeting of the Chemical Section was held after adjournment of Annual Meeting.

Mr. Jas. M. Camp, Chairman.

The minutes of the last regular meeting were read and approved.

The Committee on Chemical Literature called the attention of the Society to three papers published in the last issue of the Transactions of the American Institute of Mining Engineers, under the following titles:

A Uniform Method for the Assay of Copper Material for Gold and Silver. By Albert R. Ledoux, New York City.

Losses of Gold and Silver in the Fire Assay. By H. Van F. Freeman, Denver, Col.

The Inaccuracy of the Commercial Assay for Silver. Discussion by C. A. Stetefeldt.

The Secretary reported that he had received a number of replies to the circular letter sent out in regard to the collection and tabulation of methods of analysis of iron and steel in use in the Pittsburgh district, all heartily approving the scheme, and promising assistance. Replies from the following members were read:

Warren R. Clifton, Shenango Valley Steel Co., New Castle; Jas. Brakes, Chemist; Dr. C. B. Dudley, Chemist Pennsylvania Railroad Co., Altoona, Pa.; Jos. M. Wilson, Steubenville, O.

CHAIRMAN, JAS. M. CAMP: The question is, What shall we do in this broad field? How to get at it? Are there any suggestions?

MR. JOS. M. WILSON: Has there been a Committee appointed to do any work?

THE CHAIRMAN: The Committee has not yet been appointed. Before the Committee is appointed, there are some questions to be discussed, namely, of how many members the Committee shall consist; what the Committee shall do; where its work shall begin and end; whether the Committee shall revise or decide what papers shall be printed in the transactions,—which are fit, and which are not; or whether the Society wish to print everything that is given to it. Dr. Stahl, what would be your idea of the duty of this Committee?

Dr. K. F. Stahl: As I understand it, the duty of the Committee should be, simply, to get the methods together and tabulate them. It would be asking too much to ask the Committee to try any of those methods. Of course, if one had the time to do it, it would be all right; but it would be almost impossible for the Committee to try all of them. They may recommend some special method which strikes them as being particularly useful; or they may try that one method themselves, or appoint two or three of the members to try it.

Mr. Jos. M. Wilson: I move that a Committee of three be appointed to collect from members of the organization, and from the working chemists in the vicinity of Pittsburgh the methods of analysis used for iron and steel, and report to the Society, which may then go into a Committee of the whole to consider the report.

Mr. Wm. Coster: I second the motion.

The Chairman: Would you limit the Committee or leave it optional with the Committee to take up one subject at a time?

Mr. Jos. M. Wilson: Let them take their subjects to suit themselves, and report as they see fit to the Society as a whole, and let them consider and take whatever action may be necessary.

Question being called, the motion was carried unanimously.

Mr. Philo Kemery: Does this include alloys?

The Chairman: It is getting pretty far out to take in the alloys.

Mr. Jos. M. Wilson: That is a matter that could be left to the Committee.

Mr. Philo Kemery: We have plenty of alloy steels.

The Chairman: For copper, the analysis is the regular analysis of steel; it comes in regularly; tungsten and chromium are about the only alloys of importance.

Mr. W. E. Koch : Nickel, titanium and calcium.

The Chairman : The work mapped out is a large one, but it is an immense field. The American Institute of Mining Engineers has taken up this subject lately. The paper mentioned by the Committee on Chemical Literature, namely, "A Uniform Method for the Assay of Copper Material for Gold and Silver," is one of the results. The Secretary of the Society, Dr. Raymond, took the responsibility of fathering the idea. He got quite a lot of gold and silver-bearing quartz and had it crushed and sampled by an expert in that line, and distributed it among twenty or twenty-five assayists all over the country, and the result will be a uniform method of assaying that sort of material. Now, if that Society can take it up as a sort of side issue and make a success of it, surely we can make something out of it.

Mr. Jos. M. Wilson : You will recollect that in 1881 the Mining Engineers took up the question of collecting methods of analysis of iron and steel, and that is what gave the impetus to the modern quick methods of steel analysis.

The Chairman : Yes ; and their work is a text-book yet.

Mr. Jos. M. Wilson : You will find the methods in the 10th volume of Transactions.

Mr. W. E. Koch : A great wave of quick methods swept over the world at that time. It started up in 1879 ; it has died out now.

Mr. Jos. M. Wilson : Those quick methods have served their purpose.

The Chairman : I notice most of the works are going back to the old style methods, and dropping those methods that are so very quick.

Mr. W. E. Koch : The quick methods are good when the furnace is waiting.

The Chairman : They are good enough for that, but not as a rule to buy and sell on.

Mr. W. E. Koch: No; we must draw a line between the methods in that case.

The Chairman: I will appoint Prof. Phillips Chairman of this Committee; the other members I will appoint after consulting with Prof. Phillips.

On the Committee of Chemical Literature, I will appoint Messrs. W. E. Koch, Philo Kemery, K. F. Stahl, A. G. McKenna and S. G. Stafford.

Adjourned at 10 P. M.

A. D. Wilkins,
Secretary Chemical Section.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

February 21, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Carnegie Library, Allegheny, Pa., on Thursday evening, February 21st, 1895; the president, Mr. Thomas H. Johnson, in the chair. The meeting was called to order at 8.25, 31 members and 10 visitors being present.

The minutes of the last meeting were read and approved.

In the report of Board of Direction the Secretary read the names of four applicants for membership passed by the Board, to be voted on at the next meeting.

The names of F. B. Strunz and Seward Babbitt were then brought up for ballot, Messrs. Davis and Paine being appointed tellers. As a result of the ballot it was found that 30 votes had been cast for each applicant, and they were accordingly declared elected.

The president here appointed the following standing committees for the ensuing year:

LIBRARY.—F. C. Phillips, Maurice Coster, Geo. Faunce, W. G. Wilkins and Chas. Davis.

PROGRAMME.—H. J. Lewis, G. W. Schluederberg, Jas. M. Camp, W. A. Bole and E. D. Estrada.

RECEPTION.—Karl F. Stahl, J. A. Brashear, H. H. McClintic, Philo Kemery, T. P. Roberts, F. Z. Schellenberg and George H. Paine.

ROOMS.—Geo. S. Davison, Geo. H. Paine, Emil Swensson, Daniel Ashworth and Walter E. Koch.

Mr. Emil Swensson then read a report on the death of Mr. Carl Amsler.

To the Engineers' Society of Western Pennsylvania. In Memoriam:

It being the sad duty of your committee to chronicle the death of our fellow-member, Mr. Carl Amsler, at Pittsburg, Pa., November, 1894, we herewith submit the following as the obituary of this distinguished mechanical engineer :

He came to the United States in the fall of 1869, from Wurtemberg, Germany, where he had been educated in his profession, and at once entered the employ of the Keystone Bridge Company, of Pittsburg. He served this company first in the capacity of machinist, until 1872, when he entered the draughting department and speedily became a very proficient draughtsman, doing continuous service as such until 1879. In that year he took charge of the construction department of the Homestead Steel Works, then called Pittsburg Bessemer Steel Works, which plant was planned and executed in its entirety under his direction and supervision. In 1883 he went to Wheeling, W. Va., where he had charge of the erection of the Bessemer steel plant of the Riverside Iron Works, and when completed he operated the same for two years, or until 1887, in which year he entered the employ of the Mackintosh and Hemphill Company, and while there superintended, among other important work, the building of a Bessemer plant at Mingo Junction, Ohio, and of the original plant of Duquesne Steel Works. On the death of Mr. Schuler, of the firm of McClure & Schuler, the mechanical engineers and iron and steel plant contractors, of Pittsburg, he, in 1889, entered said firm, which changed its name to McClure & Amsler, and retained his connection with same until his death. Among some of the important works built by this firm we mention the Open Hearth steel plant at St. Louis, for the Messrs. Niedringhaus, in the execution of which he was suddenly stricken down by the Grim Reaper in the prime of life.

He was an affable gentleman, of a large circle of acquaintances and friends, an excellent engineer and an honor to his profession and an untiring worker, who never let his energies flag until the work in hand was finally completed. In fact it was this ambitious and conscientious nature of his that led him to at all times disregard his personal comfort and health, and finally carried him off when still in the harness.

The sincere sympathies of the Society are extended to his bereaved family in their loss of a kind husband and father.

It was moved and seconded that the report be accepted. Carried.

The president reported for the committee seeking quarters for the Society, that they had several places under consideration, from which it was hoped satisfactory accommodations could be obtained, but a final report could not at present be made.

THE PRESIDENT: We will now proceed with the regular programme of the evening, the first of which is the discussion of Mr. Bole's paper read at the December meeting. You may now consider the paper before you, and open for discussion. Has any one any comments to make, or any questions to ask Mr. Bole.

MR. WILLIAM A. BOLE: A paper containing several questions has been handed to me, the first of which is as follows:

"Can the losses due to friction in an engine be accurately calculated? That is, is the co-efficient of friction between piston rings and cylinder walls, cross-head and guides accurately known?"

The friction, of course, differs in different engines. It is the practice of the establishment with which I am connected—The Westinghouse Machine Company—to test engines for friction, as well as for steam consumption, and the mode of procedure is as follows: The engine is mounted on a suitable foundation and piped up, as in service, and is run at full speed. The load is applied by means of a Prony brake, consisting of a

band wheel of suitable size encircled by a good, strong flexible band of wood staves, tied together by iron hoops. This band can be drawn up by a screw and made to close in on the wheel, and that acts to depress a pair of scales. By this means, the load can be accurately measured. In ordinary practice the actual horse power could be easily calculated if we could measure the tension of the belt, the velocity of the belt, etc.

We also use an indicator and take diagrams which enable us to calculate the horse power developed in the cylinders and the frictional loss is of course the difference between the horse power developed on the scale and that as shown by the indicator. That loss includes the friction of every part of the engine, pistons, rings, bearings, and everything, and there is no other way of calculating accurately just what the friction of an engine is. That method, of course, is only applicable to engines of comparatively small size. We carry it into practice with engines up to 500 horse power, but beyond that it is difficult to arrive at any definite knowledge as to what the actual loss is. Many large marine engines develop 16,000 to 18,000 and 20,000 indicated horse power, and it is mere guess work to tell how much is effective and how much is lost in friction of the engine itself.

"Do you consider 'drop' between the cylinders of a compound engine a source of loss?"

We do always consider the drop as a source of loss, and design an engine so as to have as little drop as possible.

"Is there any way of estimating the loss due to radiation, convection, etc., from cylinder, steam chest, etc., of an engine?"

I said in my paper, I think, that the losses from radiation from all parts of the engine, including steam pipes, were comparatively small. The great source of loss lies in the nature of the agency employed, steam. This loss from radiation can be largely prevented by the use of non-conducting covering for pipes, cylinders, etc. I am uncertain as to what is in-

tended by the word "convection," but as I understand the term, the heat would have to be convected or conveyed through the cylinder walls to the outer surface, and radiated from there. If this is the correct understanding, I would answer that such losses can be largely prevented by the use of non-conducting covering.

"Is there anything gained by using steam jackets in single or compound engines?"

Some builders provide steam jackets on engines for a higher efficiency, and there are people who claim that there is no virtue in so doing. The authorities are divided. There has been a good deal said in the transactions of the various societies about the performance of the celebrated engine built by George H. Corliss, and used at Pawtucket, Rhode Island, for pumping water. This engine is provided with steam jackets, and in order to determine whether or not steam jackets were of any use, some four or five years ago several of the more prominent engine builders put their heads together and expended considerable money to test this engine, both with and without the steam jackets. The report of that test is to be found in the transactions (1889) of the American Society of Mechanical Engineers, and the experts who conducted this test say that it is impossible to tell from the results whether there is any gain or not. If there was any gain, it was too small to be appreciable, and the matter is still in doubt.

Prof. R. H. Thurston tried to give us an answer to that question four or five years ago, and he wrote to all the engine builders in the country who would probably have any information on the subject, and he simply gives everybody's opinion and leaves the public to arrive at their own conclusion; therefore, I cannot answer the question definitely.

THE PRESIDENT: Any further discussion of this paper?

MR. JOHN A. BRASHEAR: What is the average percentage of frictional losses now?

Mr. William A. Bole: Well, about 8 per cent. is an excellent result, and 10 per cent. ordinarily. The dynamic efficiency of an engine is about 90 per cent.

The President: Any further discussion? If not, we are ready for Mr. Brashear's lecture on "Optical and Engineering Problems associated in the construction of Great Tele scopes."

SOME NOTES ON THE HISTORY AND CONSTRUCTION OF LARGE TELESCOPES.

A Talk given before the Engineers' Society of Western Pennsylvania, February 21, 1895, by John A. Brashear.

Mr. Chairman, Gentlemen, and Friends:

One of the questions that is interesting astronomers to-day, and one which comes very close to the engineering profession, is that of the mounting of great telescopes. Indeed, I really believe that the immense telescopes of the future are to be built by engineers, and those of great size which have been built in the past few years have really had an engineer back of them. I think most of the mistakes that have been made were occasioned by not having an engineer to work out the problems involved in their manufacture.

The first problem that meets us in making large telescopes is rather more in the line of the chemist and the glass maker than the engineer, *i. e.*, that of producing the great discs of crown and flint glass from which the objectives are made.

When Guinand, the celebrated Swiss weaver, upset his wheelbarrow and the load of glass rolled down the mountain side, he little dreamed of the result of that tumble, for to-day, from the lesson he learned at that time, we are making the great glasses that are mounted in our modern telescopes. The problem, however, still remains a very difficult one when it comes to large discs of optical glass, for several reasons which I will give you, and which as engineers and students you will readily understand as I go along.

Optical glass, so far as its chemical constituents are concerned, is practically the same as much of the glass used in every-day life. The crown glass in our windows, and the best plate glass, is essentially the same as the optical crown glass used in our great telescopes, and the flint glass used in the flint lenses of the great telescopes is to all intents and purposes composed of the same elements as that of which we make our flint cut glass tableware, except that there is a necessary refinement in all the processes.

However, there are certain optical relations of one kind of glass to the other which must be rigorously carried out. Up to within ten years ago there were not a great many varieties of glass. Recently (probably within the last five years), Dr. Schott, of Jena, in Prussia, and his co-laborer, Dr. Abbey, have added some twenty-eight new kinds of glass, which are now placed at the command of the optician. Some of these are exceedingly valuable, and some possess characteristics never before found to exist in any glass made up to this time.

They have made some glasses which would be invaluable to the optician had they not peculiar characteristics which, unfortunately, make them unfit for optical work. If these difficulties could be overcome, glass of this kind would make a practically perfect telescope.

Dr. Charles Hastings, of Yale University, constructed an objective of this glass, and another was made at our workshop, which to the human eye is absolutely perfect. But, alas, the crown glass proved to be hygroscopic, the beautiful polish which it received became covered over with what we call a *patina*, and in the course of four or five weeks of moist weather it excludes many of the rays of light from passing through it.

This glass, then, is not available, for the reason that, while it gives such beautiful results, when newly polished, it is not stable. Recently an English optician has endeavored to use this

hygroscopic glass by placing it between two permanent glasses, making the object glass of the telescope of three systems instead of two.

On the screen you have a photographic history of one of the 40-inch discs of glass for the Yerkes telescope. In making optical glass an intense heat is applied to the batch, as it is called, so as to thoroughly melt it, and then there is introduced a stirer, which is made of the purest clay possible, and the pots are also made of the purest materials. After the glass has been stirred until it has become very thick, the furnace is closed and the heat again applied until it is melted and made very soft again. A second stirring then takes place, the purpose of which is to bring all the air bubbles and impurities to the top. When the stirring has been finished and the glass has been in the pot about seventy-two hours, every draught of air is excluded from the grate bars and doors of the furnace, as also the chimney. After it has cooled for from five to ten days, the pot is taken out of the furnace and the shell broken off. The glass is usually found cracked into larger or smaller lumps. It is a matter of chance to find pieces large enough for objectives over twenty inches in diameter.

In the crown of the 36-inch object glass of the Lick telescope nineteen pots of glass were made before a lump large enough and good enough was found in order to get the lens.

I have here a lump exhibited on the screen which weighed about 1300 pounds that came out of a pot in 1887, from which the 40-inch flint lens of the Yerkes telescope, now about finished, has been made. I saw this block of glass in the workshop of Mr. Mantois, of Paris, in 1888.

After the glass is taken out of the pot the rough parts are sawed off. You see some of the rough parts here. They are cut off by the application of a soft iron saw and the use of sand, as in sawing stone slabs by the old process.

After the glass is cut into satisfactory shape the faces of the lump are polished. After the impurities are located and ground

out, the lump is melted down into a disc, as you see it here.

After being cast into that shape the workmen commence to more thoroughly eliminate the impurities. There is something peculiar about the melting down of a piece of glass in this form. You may take a piece of glass, say the thickness of this lump; let us illustrate it here. Suppose there were a number of impurities in the block, reaching almost from the top to the bottom ; if we can get at these impurities down, for example, to within 1-10 inch of the bottom, we can saw them out with safety, but if we cut entirely through the block the disc is ruined.

When the block is not cut through and the glass is heated again, the abraided part will gradually float to the top, while the other parts will slowly sink down, but if it is cut through the abraided part will come together and the seam is left there, resulting in an imperfect disc.

To get the block into the shape of a disc it is put on a mould consisting of a circular disc of burned clay, which has been dusted over with chalk, the surface being smeared over with mucilage, so as to hold the chalk. Two half rings are now placed on top of it. A groove is cut in the ring on the outside and a wire stretched around it to hold it together ; a dome-like cover of clay is placed over all to protect it from the direct action of the flames. The glass is melted down carefully, as you can see that if great heat is applied to it, it would result in the glass being cracked, and once cracked it is ruined forever for that size of disc.

If broken, the piece may be taken for smaller discs, but it cannot be reunited in any way that the glass-maker knows of so that it may be used for an object glass.

The heat is gradually brought up, with the muffle or cover closed over the block, and when it becomes just soft enough to drop down, the heat is stopped and the glass gradually settles to the form of the mould.

Now comes the most critical part of the manufacture of

glass, viz., the annealing. Our engineers here know something about annealing, which is essentially allowing heated material, whatever it may be, to cool so slowly that the molecules may have time to arrange themselves into a natural or normal position with relation to one another. When not carefully annealed the tension upon glass is enormous.

We have had discs of ordinary glass in our workshop that were not perfectly annealed, which occasionally break into many pieces by the tension upon them, although they are apparently not disturbed.

When the optician receives optical glass from the maker he examines it carefully by polarized light to discover if there is any strain in the disc. If he finds strain, he sometimes accepts them under protest, but usually modern glass makers are very careful in this important matter, and are always willing to warrant high-class discs and replace them if imperfect.

As impurities have frequently to be ground out after the first and second annealing, it is necessary to undertake a third annealing. Unfortunately after the third annealing the discs sometimes become devitrified when taken out of the oven; instead of being transparent they are translucent or opaque, which renders them perfectly worthless for optical purposes.

I saw a beautiful 30-inch disc in Paris rendered useless by devitrification after the second annealing. This disc would have been worth about $2,500 had not this devitrification taken place.

In a disc made for a large photographic lens, considerable strain was noticed by the optician. In grinding the lens into shape it flew into many pieces, and was utterly ruined. My friend, Mr. Calver, was working a large disc for a reflecting telescope at one time, when a terrific explosion occurred; that is to say, the disc flew into many pieces, tore down the side of the house in which he was working, but fortunately Mr. Calver escaped injury. The cause of the breakage was undoubtedly a great molecular strain in the disc.

The German makers of optical glass are now annealing it by an automatic arrangement, which has produced the best results yet obtained. We have just received two discs at our workshop 23 inches in diameter, weighing about seventy-five pounds each, and so far as we can see they are absolutely free from molecular strain. They were made by Dr. Schott, of Jena.

Another trouble in optical glass is the fact that what we call striæ will form in the mass. This is glass of slightly different density from other parts of the disc, and unless it is ground out produces an imperfect image, no matter how carefully the glass may be ground or polished.

Fortunately the optician has command of methods by which he can determine both the elements of strain and of striæ in his glass, so that if he makes a careful study of his polished discs he need not run the risk of finding them imperfect after they have been made into an objective.

One other difficulty in producing a perfect optical glass disc is the fact that it may be denser upon one side than upon the other. It is therefore very necessary that the block of glass should be laid in a mould when it is ready to be melted, so that the horizontal plane which it occupied in the original pot shall be kept very nearly the same in the mould. If a glass disc is denser upon one side than the other it is very difficult indeed to bring the rays of light that pass through the lenses made from it to one single point, and it is necessary to work upon the glass "locally"; that is, polish away more in one part than another. This answers very well if the glass does not change greatly in temperature, but as observations have to be made with telescopes in temperatures differing as much as 100 degrees, it is very necessary, that this third quality, viz., "an equal density of all parts of the disc," should be as nearly perfect as possible.

Only a few years ago a disc 20 inches in diameter was considered a marvel, but Mr. Mantois has recently made discs 42

inches in diameter, and is now engaged in making a pair 48 inches in diameter, and I have the assurance of Mr. Mantois and Dr. Schott that they are willing to undertake the manufacture of glass discs up to one meter and a half in diameter, or say five feet.

I have not time now to discuss the question of the value, astronomically speaking, of telescopes made with such enormous glasses, nor shall I have time to tell you anything about the grinding, polishing and correcting of the lenses which form the object glass of a great telescope, but I may have this pleasure at some time in the future.

We will now throw upon the screen the mountings of some of the ancient forms of telescopes, so that we may compare them with those made at the present day.

We have before us one of the instruments used by the Chinese astronomers before the birth of Christ. You will see they are very elaborate in construction, and were no doubt very fine pieces of workmanship. They used no glasses in them, but all the sighting was done almost identically as we would sight a rifle. The Chinese became very expert in the use of this instrument, doing good work in their time in advancing the knowledge of astronomy.

I here show you a telescope of the seventeenth century after Blanchini. After the invention of the telescope by Hans Lippershay and Galileo, the improvements in the telescope went along very slowly, the objectives all being made with a single lens, but it was found that by increasing their length without increasing the diameter, the views of the heavens obtained were more and more perfect, until at last telescopes reached the enormous length of one hundred and twenty feet, (some glasses were made 600 feet focal length, but never used so far as we can learn), while the diameter did not exceed four or five inches.

The mounting of the instrument here exhibited is quite unique, as you will see, the bracing and methods of holding the

tube being quite similar to an ordinary bridge truss; but most of the telescopes of the seventeenth century were not mounted in this form. The object glasses in the holders or cells were secured to a ball and socket joint, and then mounted on a high pole. A strong silk string was fastened to the movable parts of the mounted object glass, and the observer—with his eye-piece placed upon a tripod—pulled the object glass around so as to bring the rays of light from the object he wanted to observe through the object glass to his eye-piece, which could be placed in the proper relation to the objective. We must have the most profound respect for the astronomers of the seventeenth century who worked with these long unwieldy instruments; for—notwithstanding the difficulty of observing with them—they made many important discoveries, and added greatly to our knowledge of the heavenly bodies.

None of these long focus telescopes were of the achromatic form; indeed, they were made of such enormous length to endeavor to get rid of the color, so far as possible, which is always associated with a single lense.

In order to get rid of such enormous lengths in the construction of telescopes, Sir Isaac Newton studied the question for the purpose of determining whether or not it was possible to shorten the telescope by placing two glasses together of different kinds, so as to get rid of the color associated with single lenses; but his great mind failed to discover what later mathematicians succeeded in doing. He therefore proposed a reflecting telescope, and with his own hands made the mirror for a small instrument, thus demonstrating its practicability.

Various forms of reflecting telescopes were soon devised, the Cassegranian, the Gregorian, the Herschelian, and other forms.

You have before you on the screen a picture of the great 40-inch reflector made by Sir William Herschel, and erected at his observatory at Slough, near London, England. You will see that the engineering problems here are totally different from

those of the telescopes we have shown you. The great mirror was cast of a composition of copper and tin, which when polished, has a very high reflecting surface.

This telescope rested upon a pivot and wheels at the bottom, and it was moved around by windlass and block and tackle, controlled by persons who were directed in the movements by the observer himself, who was mounted in a basket at the upper end of the telescope. Many important observations were made with this great instrument, but it was finally dismounted, and the mirror now rests in a niche in the wall of the home of the Herschel family, where I saw it but three years ago. The polish remains quite good up to the present day.

Sir William Herschel made many smaller telescopes of the same kind, and it was with one of these instruments of 20-inch aperature that the planet Uranus was discovered.

Later on Lord Rosse undertook the construction of an immense telescope at his home in Parsontown, Ireland, and you now have a picture of this instrumeut on the screen. Its focal length was about 72 feet, its diameter being six feet, and it is to-day the largest telescope in existence.

Lord Rosse studied very carefully the engineering problems in mounting this mighty instrument, and finally concluded that he would give it only a small amount of motion east and west, and a considerable amount north and south, and as the heavens themselves moved through the great circles, he was enabled to point his instrument from time to time at objects that had defied the smaller instruments of the past.

The speculum, or mirror, of this great telescope weighed about five tons, but it was handled with very great ease, as the whole weight was carried upon a ball and socket joint at the bottom, the weight of the telescope not having to be carried by the methods adopted in modern astronomical engineering.

You now have before you on the screen the great reflecting telescope made by Eichens for the Paris Observatory. This telescope is about 40 feet focal length, and the mirror is 48

inches in diameter, but instead of this mirror being made from a metal, it was made from a heavy disc of glass, and the surface —which was ground, polished and corrected—was silvered on the front, so that the reflecting surface is from the brilliantly polished silver, which reflects a great many more rays of light than the same area of metal, from which mirrors had previously been made.

You will see that the engineering problems involved in the mounting of this telescope are entirely different from those of Lord Ross. Here the telescope is taken hold of in the center, and the tube, with all its accessories, attached to a polar axis. The declination axis is of very massive construction. It can be swung through any part of the heavens and pointed at any object in any part of the same.

Notwithstanding the beautiful manner in which this instrument was mounted, and the perfect ease with which it was handled, it has not, up to this date, given satisfaction to its makers, for the reason that they have not been able to keep the great mirror from bending under its own weight, and when you consider that a flexure of 1-50,000 of an inch will destroy the accuracy of a stellar image in such a mirror, you can see how difficult is the problem of mounting them free from flexure.

When Euler, the celebrated mathematician, took up the problem of correcting the color inherent in a single glass, he decided that Sir Isaac Newton's conclusions were erroneous, and it was not long until Dolland made a combination of crown and flint glasses which gave results almost undreamed of, so that a telescope of only three or four feet focal length and three inches in diameter, was as powerful as the great instruments with a single lens and 120 feet focal length.

The difficulties of producing perfect glass retarded the construction of what became known as the "Achromatic" (free from color) telescope until after the discovery of Guinand, which I have already mentioned; but soon glass discs of nine, twelve and fifteen inches in diameter were available, and the

Achromatic telescope soon began to take the place of the reflecting telescope, but the latter still had valuable qualities, and is to-day an instrument very largely used for certain lines of scientific investigation.

The mounting before you, made by Sir Howard Grubb is what is called a "twin equatorial." You will see that a reflecting telescope of the Cassegranian form is mounted upon one side, and the achromatic telescope upon the other.

The telescope shown was made for Dr. William Huggins, and is a very fine piece of engineering and optical skill.

You will notice that Sir Howard Grubb boldly supports this immense instrument at the outer end extremity of a polar axis, and provides the entire instrument with a clock work, which keeps it accurately pointed to any part of the heavens. There are many interesting things to be said about this double telescope, but I will be unable to dwell upon the matter further at this time.

You now have upon the screen one of the most perfect instruments constructed in modern times. This is the thirty-six inch telescope of the Lick Observatory, Mount Hamilton, California. Its focal length is 56 feet 4 inches. The tube—the declination axis, the polar axis, and the moving parts—including the great worm through which the clock drives the telescope, as also the reading circles, rests on an immense iron pedestal of rectangular form; the entire weight of the instrument being in the neighborhood of forty-five tons. The large amount of machinery distributed around the eye end of the telescope would lead you to think it a very intricate piece of mechanism indeed, but every wheel, every screw, every handle and every device has its use, although in the later telescopes much of this paraphernalia has been done away with. The Lick telescope to-day is one of the most effective instruments in use in revealing to us the secrets of the skies.

When Messrs. Warner & Swasey, the engineers, of Cleveland, Ohio, undertook the construction of this telescope, no in-

strument of its size had ever been undertaken, the largest having been mounted by Sir Howard Grubb at the Observatory of Vienna, the telescope being 27 inches in diameter, with a much shorter focal length than the Lick Observatory instrument; but so smooth are the motions and so accurate the driving mechanism of the great clock which keeps this telescope pointed to a star, that my friend Mr. Burnham has been able to measure the distance between double stars which were so close that every other telescope in the world failed to see that they were double stars at all, and my friend Mr. Keeler, by the aid of a powerful spectroscope attached to the end of this immense instrument, has been able to tell us the story of the distant nebula, of their motions away from us or toward us, and Prof. Barnard has discovered a fifth satellite to the giant planet Jupiter, which is so small that it has hitherto evaded the scrutiny of every instrument that has been pointed toward it.

The great dome of the observatory in which this telescope is placed is also a piece of fine engineering skill. Here is a dome 75 feet in diameter, built of iron beams and steel sheeting, yet it can be moved with the greatest ease.

The floor of the observatory can be raised by the touching of a button as the observer sits comfortably upon his chair or upon his ladder; he touches the electric button, starts the hydraulic pumps, which send him upward or downward, as he desires. And this great observatory, with its wonderful telescope and its great object glass, is the result of consummate engineering skill and accurate mechanical and optical work.

There is now upon the screen the great telescope of the National Observatory at Washington. This instrument is practically built upon the same general lines as the Lick observatory telescope, but you will notice that much of the paraphernalia has been taken away from the eye end of the telescope, yet the observer has command of every motion, the instrument moving by the gentlest touch; indeed, my friends Messrs. Warner &

Swasey tell me that in the construction of the great Yerkes telescope a pressure of one pound per ton moves the entire instrument, so that it may be pointed at any part of the heavens.

No doubt most of the engineers present saw the mounting of the great 40-inch telescope presented by Mr. Yerkes to the University of Chicago, and constructed by Messrs. Warner & Swasey, of Cleveland, Ohio. In this great instrument many engineering problems came up, and much that has hitherto been done by hand, or by help of assistants, is relegated to the little electric motor, for the observer touches a button here and the great telescope moves in declination; a button here and the great instrument moves in right ascension; another there and the massive tube is swung from one side of the pier to the other, the great clock inside of the pier moving with a motion that is almost as constant as the stars themselves, and when the telescope is clamped to it, it is carried through any part of the heavens with great precision. On all of these great modern telescopes you will notice immense circles with divisions so coarse that they can be read with ease by the observer from the eye end of the telescope. These coarsely divided circles add greatly to the comfort and facility of finding a celestial object, and no modern telescope of any size is considered complete without them.

You now have before you one of the last efforts of the modern astronomer to make the conditions of observing as perfect as it is possible to attain. This instrument is called the "Equatorial Coude," and is practically the invention of Dr. Loewy, of the Paris Observatory.

You will notice that this great telescope is swung upon an axis which points north and south. In this projection at right angles to the polar axis is placed a mirror, which is swung upon a pivot, and as the entire telescope may be rotated upon its polar axis, any part of the sky may be made to fall upon this first mirror.

By ingenious mechanism this outer mirror is so set in con-

nection with the polar axis that it can be placed upon a planet or star, or any other object in the heavens, and then reflected to a second mirror, which is in the center of the polar axis. The light is then reflected through an object glass, which is placed in the body of the tube, or polar axis, and by this is thrown upward to form an image at the upper end of the axis itself. This upper end being stationary, it may be surrounded by a comfortable room, or house, where the observer, with his circles and micrometer, is able to make his observations and measurements with all the comfort one has in sitting in an arm chair in his own library.

This instrument when of comparatively small size, say ten inch aperture, has done some excellent work, but larger instruments have not been quite so successful as was hoped, the trouble lying in the fact that it is almost impossible to support the large reflecting surfaces in all positions so that they will have no flexure.

The optician may make his surfaces perfect, but to hold them there under varying inclinations and changing temperatures, is a very difficult matter indeed. Many methods have been employed to solve the problem, but as yet it has not been done to the satisfaction of the astronomer, and in the nature of the case it is likely to remain unsolved, because when the mirrors are taken into account, a bending of 1-50,000 inch is fatal to the best results. Notwithstanding this, such an instrument is valuable in certain positions of stability and for certain kinds of work. I have lately seen some of the most beautiful photographs of the moon ever taken, which were made by the aid of the great Equatorial Conde of the Paris Observatory.

Finally, we have upon the screen a picture of what we call a "photographic telescope." This instrument has been mounted in various forms, but it is essentially a telescope with an object glass corrected for photographic work only.

Alongside of it, sometimes in the same tube—as in this case—is mounted an object glass corrected for visual work

only. When the astronomer desires to take a photograph of the stars, he sights his visual telescope so that the delicate spider lines in his micrometer will bisect some star that he selects. His clock is then started, the telescope clamped to the moving axis, and the photographic plate exposed. He then watches in his visual telescope, carefully correcting any irregularity in the movement of his clock until the exposure has lasted for the time required to take his picture.

Exposures have been made in this way for thirteen or fourteen hours of time, the photographic plate being tightly closed when the twilight dawns, and the visual telescope reset when the night comes again, and whereas the visual telescope may show us a few hundred stars, when the plate is developed, where there were hundreds of stars visible, there are now many thousands on the photographic plate.

In the mounting of the photographic telescope many interesting engineering problems come into play, and as much of the work of future astronomy will be done with the photographic telescope, there still remain some interesting problems to be solved in the mounting of this instrument, but we have no fear that as the demands come upon our modern astronomical engineers, the difficulties will be solved, so far as the laws of nature will allow us to solve them, and we will gather in new facts from the great storehouse of Heaven, which is always open to the earnest investigator.

In closing it might be well to name some of the engineering problems that enter into the construction of every large instruments.

The great glasses composing the objective must be mounted so that no irregular flexure or bending shall take place under varying angles of support. The massive tube must have the the least possible flexure in all positions, from the vertical to the horizontal. The polar and declination axis must move with the smallest possible resistance. The weight upon all axes must be so taken up with anti-friction devices

that all friction may, if possible, be changed from sliding to rolling friction. A maximum rigidity must be retained in all moving parts, and the source of motion, be it driving clock, water or electric motor, must have a constant speed, or at least, have its speed under the complete control of the observer, indeed, every motion of the telescope must be under his control so completely that a stellar image may be bisected upon the delicate spider lines of the micrometer, and kept there until the astronomer has made his measurements, which are among the most refined and delicate in the whole range of nature. There are many other things of minor importance in the mounting of great telescopes, which I might call your attention to if I had the time, but I have already trespassed upon your patience. I will only add that our American and foreign astronomical engineers have already done splendid work in solving the problems presented in mounting great telescopes; and we have no fear but they will keep pace with their brethren who have to contend with the enormous difficulties surrounding the construction of the great object glasses.

MEETING OF THE CHEMICAL SECTION.

February 22, 1895.

The regular meeting of the Chemical Section was held in the Reference Room of the Carnegie Library, Allegheny, Pa., Friday evening, February 22, 1895.

The meeting was called to order at 8.15 P. M., by the chairman, Mr. James M. Camp, twelve members and three visitors being present.

The minutes of the last meeting were read and approved.

Prof. Phillips, chairman of Committee on Methods of Analysis, recommended that the committee work for the pres-

ent be confined to methods for iron ores, pig iron, and steel. After remarks by the chairman, Mr. McKenna, Dr. Johnson, and others, it was moved, and carried, that the work be limited as above.

Prof. Phillips then asked what should be considered the geographical limits of the work. The chairman and others thought the committee should collect methods from all the members of the society, and as many others who would reply to circular letters, to be sent out by the committee.

The chairman then appointed the remainder of the committee, which is as follows: Prof. F. C. Phillips, Western University, Allegheny, Pa.; Dr. E. S. Johnson, Black Diamond Steel Works, Pittsburg, Pa.; Mr. A. G. McKenna, Duquesne Steel Works, Duquesne, Pa.

The following paper was then read by Dr. Johnson:

THE CHEMICAL INSTITUTE OF HEIDELBERG UNIVERSITY.

BY DR. E. S. JOHNSON.

In accordance with the great importance of the science of chemistry, considered as a science and also from a utilitarian point of view, throughout our own country, higher institutions of learning have long since given it a prominent place in their courses of study; some of these have already developed, and others are rapidly developing into schools of chemistry. Abroad, connected with the universities of most lands, there exist extensive establishments, largely state institutions, for the professional training of young men in both the science and art of chemistry.

Notably in Germany, the land of method and thoroughness, the specialization in this direction is carried still farther, and has received expression in the form of the chemical

institutes of her universities and great polytechnic schools, each with distinct functions, and serving distinct purposes. The universities and polytechnic institutes are, however, *alike* in being pre-eminently professional schools—schools for the training of specialists. The aim of both, in whatever faculty or department, is the development of the student into a thoroughly equipped, independent thinker and worker in his profession.

At *the universities*, science is studied purely as such, for its own sake. In their chemical institutes, therefore, pure chemistry is the "motif" of all activity. In the lecture-rooms of the institutes, by courses of lectures elaborately illustrated by experiment, the phenomena of the science are placed before the student, its principles are expounded, and its scope and application developed. In their laboratories he becomes intimately acquainted with the implements and methods of chemical experimentation. Thus, by a combination of tuition and practice, *the acquisition of a knowledge of the methods of chemical research* are placed within the student's grasp.

At the *polytechnic institutes*, on the other hand, *applied science* is the object of study. In the development of the spirit of inquiry and research, here, as at the university, a main object in the student's training, as you remember, the discussion of questions and solution of problems, relative to technical matters, form the chief exercises.

The study of the applications of a science naturally presupposes a study of the general science itself. Corresponding provision is made to meet this requirement in all departments of the various polytechnics. This feature places the schools of applied science on a footing entirely independent of the universities. Each, therefore, has its separate sphere of activity and influence.

But we must return to the universities, to HEIDELBERG UNIVERSITY, and, more particularly, to its CHEMICAL INSTITUTE, the subject of my remarks this evening.

I. Historical Sketch.

The venerable and famous university of the quaint, picturesque "Musenstadt am Neckar" needs no introduction to any of my hearers.

During long and efficient service of more than five centuries, in the acqusition and dissemination of learning, it has become universally known among the friends and disciples of higher culture, and won a distinguished place among the world's great universities.

In 1886 the institution celebrated, with just pride and with pompous ceremony, its 500th anniversary. As an appropriate memorial of the occasion, the "Aula," the university Assembly Hall, the meeting-place on academic days of festival or other import, of professor, student, and philister, had been redecorated and furnished in magnificent style, yet with dignity and in perfect harmony with its purpose. The photograph I am able to show you will serve better than description in helping the imagination to a conception of the work. You will notice the rich decorations of the joiner and wood-carver on the walls and ceiling. On the end wall, opposite the entrance, is a fine allegorical painting, representing the "Founding of the University." The ceiling has four paintings, allegories on the four faculties. Below, to the right and left, are portraits of two princely patrons of the institution, Elector Rupert I., its founder, and Prince Charles Frederick of Baden. Under the patronage of the latter the university underwent a great restoration after a period of decline, resulting from the disturbances of the Thirty Years' War.

In the center is a marble bust of the present patron and rector of the university, the Grand Duke Frederick of Baden.

But that to which I more especially wish to direct your attention are the panels on the walls above the windows and in the sections of the ballustrade of the gallery which extends around the hall. These bear each a name, and are memorials to celebrated professors of the various faculties, who made the

university famous in the earlier periods of its history. The renown created by these men has lost none of its luster with the advance of time; on the contrary, a galaxy of successors has handed it down, perhaps with increased radiancy to our own day.

Among the names of men of science of this proud distinction, are those of Czerny, Erb, Gegenbauer, Helmholtz, Kirchhof, Kopp, and Bunsen.

The name of Bunsen has an especial pertinence to the subject of this paper, since, with the call of Prof. Bunsen to the professorship of chemistry in Heidelberg, the chemical institute of the university first assumed a prominent individuality.

In the first decades of the century, chemistry was taught at the university, as was almost universally the case, as a part of physics. The professorship of physics, however, was finally divided, two professorships, that of physics proper and of chemistry, resulting. Chemistry having thus attained an independence, *Gmelin*, known to you as part-author of Gmelin-Kraut's Handbook of Chemistry, one of the first encyclopedic text-books of the science, for his prominence in the theoretical discussion of his time, and for important contributions to inorganic chemistry, was the first* incumbent of the newly-created professorship. During his occupancy of the chair, the institute was naturally of very modest proportions.

With the accession of *Bunsen* in 1851, a new epoch was begun, and the work of this great man in Heidelberg, extending over a period of nearly forty years, has made the old town classic ground in the history of chemistry.

His researches, I need not remind you, embrace nearly

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*This statement is made from memory of an impression gathered from conversation or reading while the writer was in Heidelberg. Having scarcely thought of the matter since, and not having had opportunity to confirm the impression since the commencement of this paper, he wishes to make the statement with requisite reserve. E. S. J.

every department of inorganic chemistry. The pages of analytical chemistry are illumined with his work; his investigations on gaseous bodies laid the foundation of modern gas-analysis. But the crowning researches of his life, carried on jointly with his friend and colleague, Prof. Kirchhof, then professor of physics in Heidelberg, were those in spectroscopy, which led to the discovery of spectrum analysis, declared by Ernst von Meyer in his History of Chemistry to be the greatest scientific discovery of the last fifty years.

Although now no longer active, Prof. Bunsen, having retired on account of his advanced age, is still connected with the university as honorary professor, "a pride and ornament of the Natural Science Faculty."

In the fall of 1889, *Prof. Victor Meyer* was called to Heidelberg to succeed to the professorship made vacant by Bunsen's retirement, ushering in the present period in the history of the institute. He entered upon his work by re-adapting its old laboratories and the construction of new laboratories for the study and advancement of organic chemical science.

II. The Buildings of the Institute.

Bunsen's researches had been, in the main, in the field of inorganic chemistry, as you remember—his interest was centered there, his fame was largely achieved there—and he was content, as well he might be, to remain devoted to his adopted work, unallured by the developments, during the last twenty-five years, in organic chemistry, which have been of such vast importance, both to purely scientific and also applied chemistry. Moreover, he was so accustomed by his long experience to the exact work of analytical and physico-chemical research, that organic work, lacking the exactly quantitative element of inorganic analysis, and frequently the cleanliness, was distasteful to his nature and habit. The brilliant researches of his celebrated colleagues Liebig, Wöhler, Hofmann, Frankland, Kolbe, and later

eminently of Baeyer, Victor Meyer, Curtius, Fisher, and others, were unable to attract him into the same field of investigation.

Besides devotion to inorganic chemistry, a marked simplicity characterizes the work of Bunsen. He delighted in the accomplishment of his purpose by the simplest possible means. His researches were executed, whenever possible, by apparatus of extremely simple construction. The large number of simple, ingenious, now almost indispensable pieces of apparatus, supports, stands, burners, combustion-furnace, familiar objects in every laboratory, testify strikingly to this characteristic.

The nature of his work and its method have placed their impress, naturally, upon the building erected under the direction of the professor in 1852 to accommodate the Chemical Institute of the University. The building is still in use, and devoted to its original purpose; it contains the inorganic laboratories of the institute.

A. The Old Building. In asking your attention to the older building, I shall do so mainly on account of its interesting associations. It would be foreign to my purpose, therefore, to enter into architectural details, dimensions, etc., any more than may be necessary to clearness in the few general references I shall make to the building itself.

The old institute is situated near the center of the town, and fronts on the small public square known as the "Wredeplatz," which twice each week is the scene of a characteristic feature of life in the towns, and even the cities, of Germany. The photographs, I hope, will make the allusion plain.

As already intimated, the building is architecturally very plain. The front end, visible in the photograph, is probably 50 feet in width, of two stories, and contains the residence of the professor, the director of the institute.

The laboratories are in the rear, in the part of the building facing on Academy street, and extending back a distance of possibly 100 feet or more. The public entrance is in this facade of the building.

I shall ask you to enter with me for a rapid tour of the interior. On entering, perhaps the first thing which would attract the eye of the foreign visitor—the interior itself being very unpretending—would be the array of announcements coving the blackboard, "*das schwarze Brett*," of academic fame in Germany. Here the professor and assistants of the institute communicate with the student as to when and upon what subjects lectures will be delivered during the current or coming semester, as the case may be. Other professors of the Mathematical and Natural Science Faculty, whose lectures might interest the student of chemistry, also make their announcements here. The communications on the blackboard form thus the channel of business intercourse between professor and student. The custom is universal in Germany.

On the opposite side of the hallway, we notice, in rather amusing contrast with the intellectual program just considered, a similar board full of advertisements of "rooms to let," of enterprising "restaurateurs," whose "board and beer are the best in town," and of merchants whose stores offer convincing, unquestionable bargains particularly interesting the student.

Directly opposite the main entrance, at the end of the short hallway, is the door opening into the present laboratory for quantitative analysis. At the side of the door to the right, we observe the directing notice "Zum Grossen Hörsaal." Following the direction indicated along the narrow hall to the right, passing several smaller rooms variously applied as library, balance-room and private laboratory, we enter the famous old *lecture-room* where many of the foremost men of the profession, both in Europe and America, sat under the tuition of the great Heidelberg professor.

The general remark is at once at the primitive appearance of the place. From in front of the lecture-table, gradually rise tiers of simple benches for an audience of about 100 persons. Nothing but the associations could interest the visitor.

We return to the entrance to the present *quantitative laboratory*, just mentioned. Within we find a commodious room occupying, with the adjoining room on the street side of the building, the main part of the latter in the rear of the professor's residence and the lecture-room. Floors are of asphalt-cement. Large windows overlooking the professor's garden admit abundance of light.

Before the windows, and standing in the middle of the room, the latter placed their length parallel to the width of the laboratory, are the work-tables. The tables are constructed on an old and very plain model, consisting of a pine case with cupboards and drawers, and hardwood top, in length three or four feet, in width some twenty inches. Those in the center of the room are placed back to back, in pairs in the usual way, men working face to face, while, at the windows, side by side. The usual shelves for reagent-bottles, etc., are present. The series of hoods along the wall opposite the windows, together with many other conveniences, are marks of the re-adaptation period.

In Bunsen's time the laboratory, I am told, was practically without hoods.

In the end of the room to the right of the door which admitted us, is the entrance to what *was* the "sanctum sactorium" of the old institute, *the private laboratory* of Prof. Bunsen. We must enter here, if but for a moment. Like all parts of the old building, this also has changed in appearance with the change in regime. The original work-tables are still in place, but very little else is left. The former occupant might, perhaps, with difficulty, recognize the old workshop. However, no matter how greatly the appearances of things may change, the old laboratoay of the great master of chemical research will remain a spot of intense interest to the student of physical science, whether he be physicist proper or chemist. The recent changes wrought there do not prevent the imaginative from picturing the great investigator busied with his friend, Kirchhof, in spectroscopic research, or discussing with

his since distinguished pupils, experimental questions relative to their joint researches, many of which have resulted in conclusions of liveliest import to the progress of science.

But we must withdraw from the magnetic influence of the "sanctum" to hurriedly continue our tour of inspection. Adjoining the laboratory into which I first ushered you, is that now used by students of *qualitative analysis.* Its equipment being so similar to that of its neighbor, we shall pass rapidly through, emerging into a hall, at the end of which is the north exit from the old institute, and the entrance to the enclosed passageway connecting the old and new laboratories.

However, we are not quite ready to leave the classic precints of the old institute. One other place in the building still deserves a visit. You recall my reference of a few moments ago to Prof. Bunsen's *researches on gaseous bodies*, transmitted to us, as you remember, in his now celebrated work entitled "Gasometric Methods." The scene of these investigations was a room, perhaps 15x25 feet, occupying the northeast corner of the building. Within there is nothing to suggest the original object. The historic apparatus has been removed, the room divided into two, the parts serving as combustion and balance room. The old gas-apparatus, however, has been carefully preserved, with the respect due it; and, since the completion of the recent additions to the institute, has been returned, much of it at least, to an honored place in the new gas-laboratory which occupies the site of the old laboratory, the latter having shared in the general restorations of the building to its former sphere of activity.

Before our visit to the organic laboratories, I should like to have you come with me for a moment to the half-storied *garret*, a store, to be sure, of much rubbish, but also of objects replete with interest. Strewn about the place when I first saw it, in the fall of 1889, just after the remodeling of the laboratories, were pieces of apparatus used by Bunsen in his spectroscopic, photo-chemical, and other investigations. Interesting

preparations and materials, the agents and subjects of research, were to be found here and there on dust-covered shelves. Among them I one day noticed some packages labeled "Platinum Ore." Afterwards I learned that this material had been sent Bunsen by the Russian Government for investigation; the results were embodied in the professor's valuable contributions to the chemistry of the plantinum metals.

Numerous other objects of interest and moment would attract the attention of the curious in this direction, but we must refrain, and I shall now request you to accompany me through.

B. The New Building of the Institute. As containing one of the most recent and best adapted equipments of the present time for study and research in organic chemistry, the new structure claims our attention somewhat more in detail than the older building. However, as in the case of the latter, we shall not discuss plans, architectural features, and the like, except where such are of special significance; this would only weary you. I shall confine my remarks to general references to the main features of the building as such, and conduct you then, as entertainingly as I may be able, through the interior of this busy hive of chemical science.

The site of the new building almost adjoins that of the old laboratory, the garden of the professor's residence intervening, and, as already pointed out, an enclosed passageway makes communication ready and convenient.

The building itself is perhaps even more unpretending externally than its neighbor to which, in style and materials, it is similar.

Its proportions display little beauty, it being long and narrow, and comparatively low, standing in this respect in glaring contrast with many other laboratory buildings of the country, such, for instance, as that of the Polytechnic Institute in Aix-la-Chapelle, Hanover, Zürich, or Berlin, of which I have a photograph to show you; or the magnificent Chemical Institute of the University of Strasbourg.

The proportions were necessitated by the site, the only one available for the purpose, and the fact that the space for the building must be utilized to the utmost in order to meet the demands made upon this department for room.

The building, however, is so hidden by its environment that little more than the roof and the tall, factory-like draft-chimney is to be seen by a critical public, except, perhaps, the good housewives of the surrounding dwellings. In view of its position, and of the comparatively limited appropriation placed at the disposal of the institute by the government of the Grand Duchy of Baden, the patroness of the university, for the erection of the new buildings, it was deemed wiser to provide bare necessity as regards exterior, saving thus to the fund for internal equipment.

The building is, I guess roughly, 50 feet wide, and stretches out to a length of perhaps 130 or 140 feet, standing its length practically parallel to that of the old building; it is of two stories, except at the north end, which is surmounted by a third, containing the lecture-room and accessories.

In our imaginary tour, I should like to invite your attention, in the following order, to *the lecture-theater*, *the general laboratories and their accessories*, and *the private laboratories*.

1. Lecture Theater. As the place where the student receives his initiation into the mysteries of chemical science, the lecture-room forms an appropriate starting-point.

Entering, we find ourselves within an amphitheater seating about 200 persons. After some difficulty in avoiding those already taken by right of pre-emption, indicated by visiting cards attached by the regular attendants of the lectures at the beginning of the course, we secure seats in the upper tiers, which will overlook the scene about to be enacted. Our purpose has brought us early. The lecture is announced for 9 o'clock, but does not begin until fifteen minutes later, in accordance with a general custom, the professor allowing a quarter of an hour—the so-called "academic

quarter"—for the assembling of the students, some of whom must come from other institutes of the university, which, especially at the older institutions of the country, are usually found in more or less widely separated parts of the town or city.

As the audience assembles, we make use of the moments in looking about us.

The amphitheater occupies the whole width of the building, and from the entrance to the rear wall is perhaps forty feet.

The large windows of the east and west walls, *i. e.*, to the right and left, and the skylight, admit *light* in abundance. The view from the east windows, on our left, out over the quaint red-tiled house-tops and up to the old castle, at once attracts the eye. It is particularly charming. For evening gatherings or on dark mornings, when the Neckar fogs have enveloped the town, Siemen's regenerative gas-lamps provide illumination.

By means of traps in the windows and skylight, and gratings in the walls near the ceiling, thorough *ventilation* is secured.

The *lecture-table* next fixes our attention. In its description, and in that of the draft-chamber, or hood, behind it, the photograph I have with me will be of assistance.

The table is covered with apparatus for the morning's demonstrations. Two assistants are moving about, busied with the preparations and the careful inspection of the arrangements to insure a successful execution of the program.

On the table you notice the usual attachments for gas and water in abundance, the sinks at each end with water-pressure pumps, connections for condensers, etc. Near each end of the table is a cast iron draft-funnel—a sort of lecture-table hood. The form is that of an inverted U, with one shank shortened. One end, that of the longer shank, is counter-sunk in the table over a connection with the central draft of the building.

It is merely set into place, and, therefore, easily removed, when the disc, seen on the table beside it, may be placed in the opening. The free end of the pipe expands to several times the diameter of the tube itself, forming a funnel. The arrangement—a device of Prof. Meyer—is most useful and efficient for conducting off the disagreeably smelling and irritating gases and vapors produced, as you well know, in numerous experimental demonstrations of a course in chemistry. Where elaborate demonstrations are made, audience and demonstrator plainly need protection. The draft-chamber, usually behind the lecture-table, frequently requires the lecturer to stand in his own light in many small, yet striking and highly illustrative, experiments which are impossible in the unconfined air of the room. By means of the draft-funnels, such experiments may be performed in full view of the audience. Other convenient applications you will also think of. I need not point them out.

In the projecting front part of the lecture-table—where the panels are to be seen in the photograph—are closets containing special and general apparatus for the exclusive use of the lecture-room.

The *draft-chamber*, back of the table, deserves our especial notice, being a very essential feature of the equipment. With a few comments, the photograph will make its arrangement plain.

The frame work, standing out from the wall, is supported by bracket-like pillars of brick masonry, on which, forming the bottom of the chamber, rest thick slabs of red sandstone, quarried in large quantities near Heidelberg. The interior is lined with white glazed tiling. The openings into the flues may be seen in the wall, near the bottom of the chamber. At the top are others, not visible. Both may be closed by a sliding door.

The upper half of the front of the hood is fixed and of glass, the lower half is a counterpoised blackboard. The wing of the chamber on the right in the photograph opens into the

preparing room adjoining, from which, through the opening, apparatus required at a certain point in the lecture may be conveniently and promptly introduced, or other apparatus removed.

Over the doors, to the right and left of the hood, are suspended horizontally from pulleys, one over each, *wooden rods*, several feet in length. Their evident purpose is to aid in the display of drawings, tables, and other similar auxiliaries of the lectures.

While you have thus observed and classified these essentials in the appointment of the lecture-room, much more rapidly than I have been able to point them out in words, as you sat awaiting with me the approach of lecture-hour, the seats, vacant when we entered, have all been filled. An almost motley assemblage has gathered. Students from the several provinces or Germany constitute, naturally, the body of the audience. However, a large deputation of foreigners, a conglomeration of Russians, Austrians, Scandinavians, Englishmen, and Americans, scarcely ever fails. An occasional Frenchman even appears at the institutes of the German universities.

The clock now points to 9.15 ; as punctually the door on the right opens, and the professor, followed by the lecture-assistants, who have retired in the meantime, enters. He is greeted by a vigorous stamping of feet.

We have before us one of the foremost leaders in the thought and research of the chemical science of the present, an enthusiastic and brilliant lecturer, Prof. Dr. Victor Meyer. He enters at once with characteristic fluency and enthusiasm upon his subject, explaining and demonstrating by experiment with rare skill. We are entertained and instructed for three-quarters of an hour, when the professor retires, as he came, amid energetic applause.

The PREPARING ROOM, from which the professor entered, is a very completely furnished laboratory for the especial pur-

pose of making the extensive preparation required for each day's demonstrations, and serves also as the private laboratory of the lecture-assistant. Its equipment is, in its main features, similar to those of the general laboratories, which we shall in a few moments make the objects of close inspection. First, however, the comprehensive Museum or Collection, for use in the illustration of the whole course of lectures on inorganic and organic chemistry, claims our attention. Its content, I need scarcely mention in detail; you have already pictured within handsomely arranged collections of minerals, chemicals, and other natural, together with artificial, products for the purpose indicated.

2. The General Laboratories. In pursuance of our plan, the general laboratories should next be inspected.

Descending from the museum, we visit on the second floor the Main Laboratory. The general view shown in the photograph—that from the end opposite the entrance—will aid in the formation of a conception of its arrangements.

You notice at once the rows of tables extending down the length of the room, leaving a broad central aisle and two narrower side-aisles.

On either side, along the walls, is a series of draft-chambers in such number that each student virtually has one for his exclusive use. General ventilation is otherwise efficiently provided for by the usual appliances.

Abundant light is admitted by the large skylight and the windows of the west wall.

The floor is the so-called "Parquetboden," consisting of narrow, short pieces of oak flooring of uniform dimensions, set in asphalt-cement and laid end to end at right angles, so that the apexes of the angles form lines parallel to the long and short dimensions of the room.

After this general view of the laboratory, it may be of interest to examine somewhat more closely the arrangement and equipment of the *individual work-table.*

These, with a few explanatory remarks, you will be able to gather from the photograph.

In their construction, convenience and practicability have had the main consideration, and the esthetic only in so far as consistent with the circumstances—a large laboratory in which men of every degree of habit as regards cleanliness and carefulness in work (many of very indifferent excellence in these respects) may be found.

What has been referred to as *a* table consists really of *two*, back to back, as in the old laboratory, and accommodates in this case, usually, four students. Each is about ten feet in length, twenty-five inches wide, and three feet high. With the exception of the top, which is of thick polished oak, they are built of pine. The various attachments—gas, water, air-pumps, sinks, etc.—are plainly visible and of obvious purpose. On the table is a combination of well adapted shelves and racks. The shelves are supplied with half-liter reagent-bottles with enamel labels. The bottles contain the concentrated and dilute mineral acids, the alkalies, and alkaline carbonates. Other reagents are to be found in the cases of reagents for general use.

The racks enable the student to keep constantly on hand a stock of *dry* test-tubes, flasks, etc., a prime necessity in organic work. The question, in considering the applicability of glassware to a particular operation, in this case, is not so much "Is it clean?" as "Is it *dry?*"

In the center of the table, projecting from the shelving, is a draft-funnel, like those pointed out in the lecture-room.

The equipment of the table comprises retort-stands, with numerous rings and clamps, tripod-stands, tripods, melting-point apparatus, large exhaust-exiccaters, water-baths, several burners, upright and low-down crown Fletchers, etc., as seen in the photograph. Glass and porcelain ware, and chemicals, mainly, are furnished at the student's expense.

The hoods scarcely require further remark. Their general

form you see. They are all built on the brick pillar-brackets carrying the heavy red sandstone slabs, as in the lecture-room, and are lined with white tiling. To accommodate long reflux-condensers, etc., the ceiling is high. The gas and water-mains supplying the hoods are run along and underneath the front edge of the slab, about twelve inches below it, and rest in notches in the pillars. Numerous constant-level water-baths, air-pumps, etc., are distributed among them.

Before leaving the main general laboratory, two other features should be pointed out—the *glassblower's table*, indispensable in the drawing out of bayonet combustion-tubes, the sealing of the so-called "bombs," to which I shall again have occasion to return, and numerous other manipulations of like nature, which you recall; and *the fire extinguishers.*

The inflammable fluids employed in the operations of a large organic laboratory constantly expose it to danger from fire. Small fires, resulting from insufficient care in manipulations with alcohol and ether, are of common occurrence. These are easily quenched by the use of sand, which is placed within ready reach in all parts of the laboratory. An occasion of this kind often results, in fact, generally, in the display of a touching generosity. Students in the immediate neighborhood of the fire rush to the scene, plying the sand-scoop with a vigor scarcely warranted by the insignificant nature of the case, covering and filling everything, extinguishing the fire in a trice. The innocent (he is usually a first-semester man in organic work) is overcome; not, however, with emotions of gratitude—with *sand*! If the student has furthermore been unfortunate enough to set fire to his clothing, the shower-jet is called into service.

Throughout the institute very thorough general provision has been made against fire. Lines of hose are distributed in various parts of the building, where they may be readily connected with the water-mains.

Having thus considered the chief features of the larger general laboratory, the Smaller Laboratory on the first floor should receive our attention. However, we shall give it but a hurried glance; the equipment is quite similar to that of the laboratory we have just examined, perhaps too exhaustively.

The space occupied by the smaller laboratory lies to the right of the main entrance and west of the hallway, and is thus about one-half the available work-room, on the first floor, in the south wing of the building. The appointments are admirable throughout. The double work-tables, in a single row, are perhaps even more conveniently modeled and better fitted for their purpose than those above. I should like very much to refer to some special features of the tables, but lack of time forbids.

Across the hall from the smaller laboratory is the space allotted the Photo-Chemical Laboratory. The appliances for for work have not yet been supplied. We pass the empty, unfinished rooms hastily by, with pleased recognition of their possibilities, and proceed now with our tour of the Accessories of the General Laboratories.

The *combustion-room*, so indispensable to the work of an organic laboratory, invites our attention first.

It is entered from the end of the main laboratory opposite the entrance to the latter, and is, therefore, in the extreme south end of the building. I have here a photograph showing the principal features of its equipment. Extending around the walls of the room and across the center, are tables bearing ten or fifteen furnaces of the usual pattern. The tables are constructed, as you notice, on the model of those on which the hoods of the laboratories rest, and of the same materials. Over the tables which stand against the wall, is a sheet-iron canopy—which perhaps deserves mention—under which are draft-openings. The object of the device is apparent. The walls underneath the canopies are tiled.

Adjoining the combustion-room, but entered from the

laboratory, is the so-called *cannon-room*, where reactions are carried out in sealed tubes at temperatures varying, according to the object, from 100° C., or less, to 300-400° C. The tubes or "bombs," as they are familiarly known, as a matter of course, frequently explode with terrific violence, and hence the name of this part of the institute. The disposal of things may be seen from the photograph. The tables, walls, and canopies, you have already noticed, are similar to those of the combustion-room.

The construction and use of the furnaces of the cannon-room may not be entirely familiar to all. I have here, in the first volume of an excellent presentation of the subject of Organic Chemistry, by Profs. Meyer and Jacobson, an illustration which will throw light upon these points. For lower temperatures hot water is used for heating, when the furnace is of somewhat different construction. The necessary modification, however, will be apparent. Higher temperatures are produced by gas from burners of evident construction. To prevent loss of heat and facilitate the regulation of the temperature of the furnace, the latter is covered with asbestos board. The illustration makes plain the disposition of the reaction-tubes in the furnace. The open end of the steel tube, which contains the glass reaction-tube, faces the wall. In case of an explosion, its violence is spent against the tiling.

Leaving the cannon-room, we shall return through the main laboratory to the hall from which we entered. Beginning at the farther end, we may visit successively the steam-room, the balance-room and library.

The *steam-room* extends over the whole width of the north end of the second floor, and perhaps 20 to 25 feet of its length. Two tables of the now familiar construction stand in the center of the room, their length parallel to its long dimension. They are furnished along the medial line with a large number of taps for steam and water. At each end is a large hewn stone sink.

The use of the room you have already anticipated. It finds constant and convenient application for heating baths upon which solutions may be evaporated, preparations dried, and inflammable fluids safely distilled; in the carrying out of "steam distillations;" and in conducting many other similar operations. It is furthermore the scene of operations with hydrochloric acid gas, sulphuretted hydrogen, chlorine, and other reagents, alike disagreeable and effective, for which numerous draft-chambers along the wall opposite the entrance have been built.

On the first floor of the building, directly underneath the one just described, there is another steam-room. In appointment, it is almost identical with the one above, and, I need scarcely add, is supplementary to the smaller general laboratory and its neighbors.

We shall now enter the *balance-room*, spacious and handsome, and furnished with 14 or 15 short-arm balances by Sartorius, of Göttingen. The balances stand, except two or three on the long center-table, on slate shelves bracketed to the walls, each one on a separate shelf. The student furnishes his own set of weights. A case with locked compartments is in the balance-room for their safe and convenient keeping.

The *library*, adjoining, is an interesting and indispensable adjunct of the institute; a complete repository of reference of the chemical literature of the past and present, it is plainly a necessary and invaluable aid to the research-work constantly in progress in the laboratories. Its contents are neatly arranged and easy of access.

Several other features supplemental to the general laboratories must now be glanced at, if but hastily, in concluding this part of our tour. Descending to the first floor, we enter, a moment only, the *warerooms*, where students purchase their supplies of apparatus and chemicals. The cellar also has interesting features, among which may be pointed out the *fire-*

proof room, for experiments or operations of long duration—covering weeks of time, for instance—and which involve danger from fire.

Researches of recent years point to a bright future for the application of the electric current in the decomposition and synthesis of organic compounds. Work in this field has been, and, I believe, is still in progress at the institute in Heidelberg. The current for electro-chemical studies is supplied by a small *dynamo-machine*.

We have now wandered through the various parts of the new buildings, which more particularly concern the student.

There remain for our consideration:

3. The Private Laboratories of the Director of the Institute and his Assistants. To the appointment of these laboratories, little reference need be made, it being that of the general laboratories, with perhaps more attention to certain conveniences and to an elegance of appearance—according to the occupant's taste in such matters—which, for obvious reasons, are impracticable in the general laboratories.

The German professor is distinctively a specialist, an investigator. The fact that he holds a professorship presupposes a wide distinction for research in his profession, the furtherance of which is the great object of his life.

For the promotion of research and the dissemination of its results, if he be a scientist, an institute, with laboratories for students, and private laboratories for himself and assistants, is placed at his disposal by the state. An abundant salary places him on an easy financial footing, and leaves him free for devotion to his studies.

To the work of the private laboratory, a large portion of his energy is given. It is the investigations proceeding from the private laboratories of the various scientific institutes of the country, therefore, which give them a distinguishing tone, and make the intellectuality active in them, the men directing them, of especial interest.

I should like, therefore, in conclusion to present to you in a few words:

III. The Faculty of the Institute.

Prof. Victor Meyer, the Director, during the twenty odd years of his professional career, has risen rapidly and brilliantly to a leading place in the profession. At the unusually early age of twenty-two or twenty-three, he became "ordinary professor," his first call being, if I mistake not, to the Polytechnic Institute in Zürich, Switzerland. While there he directed the erection of one of the finest chemical laboratories of Europe.

After the death of Wöhler, the famous Göttingen professor, in 1882, Prof. Meyer became his successor. Among his first innovations was the commencement of a now handsome and well appointed organic laboratory.

Scarcely was this completed when, in 1889, the professor was called to Heidelberg to succeed Prof. Bunsen. The old institute not having adequate arrangements for the work in which Prof. Meyer is most interested, that in organic chemistry, it is said that the addition of an organic laboratory building to the institute was made by the professor one of the conditions of his acceptance of the chair. However this may be, the laboratory was built, as you have learned at length, and with material advantage from the professor's extended experience in this direction.

His researches have been conducted both in the field of inorganic and organic chemistry.

You will recall his *vapor densities studies* which resulted in a very practical and widely applicable method for the determination of the specific gravity of vapors, and further in imporant theoretical conclusions deduced from the results of experiments demonstrating the dissociation of the molecules of certain elements and compound bodies.

Among experiments conducted with the elementary substances, those on the halogens, oxygen, and nitrogen are of unusual interest.

The experiments made with the sesqui-chlorides of aluminum, iron, and chromium proved the valency of these elements to be trivalent, rather than tetrad, in these and analogous compounds. Valuable conclusions were arrived at in regard to the atomicity of other elements, notably in the case of mercury.

While a student with Kolbe, Victor Meyer's discovery of the first member of the series of aliphatic nitro-bodies, *nitromethane*, attracted wide notice and led to numerous other important discoveries.

At the Polytechnic Institute in Zürich, during his professorship there, Prof. Meyer discovered *thiophen* and opened up thus an extended chapter in organic chemistry. The thoroughness and brilliancy of the research in this connection gave him a high rank as an investigator.

Of later years he has been occupied with investigations on *stereo-isomerism as exhibited among the oximes.* Numerous other investigations were conducted during his first years at Heidelberg, and the work continues.

In the work of instruction, Prof. Meyer is ably supported by a CORPS OF ASSISTANTS. Professors Gattermann, Jacobson, and Dr. Knoevenagel supplement him in organic chemistry, while Professors Jannasch and Auwers have direct charge of the analytical laboratories.

Like the director of the institute, each of these men has a private laboratory and one or more assistants carrying on research under his supervision. All of them are enthusiastic and successful in research, being already well known to the profession.

To give but a partial sketch of their work would lead beyond the reasonable compass of this paper, and the few general references already made must suffice.

Completeness would require the devotion of my concluding remarks to the students of the institute, their work, and recreation. I say *recreation*, because the German, and particularly the German student, goes about his pleasure as methodically and studiously as his work. I must, however, resist the temptation, having already trespassed too greatly upon your patience.

I am deeply sensible of the imperfection of the foregoing attempt to concisely, yet clearly, present to you the past and present of the School of Chemistry of the University of Heidelberg.

If, however, you have gathered a notion of the method and means for the study and furtherance of chemical science in Germany, of which my subject is a representative type, or if conceptions, which you may already have had, have been rendered more definite or have been broadened, my chief object has been accomplished.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

ANNOUNCEMENT.

In the future the Society will mail to its menbers and correspondents, postage prepaid, ten monthly pamphlets yearly ; each one including, when practicable, the minutes of and the papers read at the regular meeting, and meeting of the Chemical Section of the preceding month.

The pamphlets are for sale at 75 cents each. Subscription price, $7.00 per annum.

In addition, any paper which the author desires to be distributed being read will be mailed separately.

The following Rule of the Board of Directors is as follows:

An author of a paper is entitled to twenty-five copies, if printed. In addition he can purchase fifty or more copies extra at first cost to the Society, plus 10 per centum, provided the order is forwarded before the type is distributed. These papers can be issued with pamphlet covers when desired.

With the publication of Volume X, the printing and binding of our TRANSACTIONS as an Annual, by the Society, ceased. The paging of the Monthly numbers, however, will be made consecutive, and at the end of the year a title page and index will be provided, so that members may have them bound into a volume uniform with preceding ones.

Copies of Volume X. for 1894 will be mailed to each member who has paid his dues for 1894, upon the receipt of 15 cents for paper covered or 35 cents for cloth bound.

Extra copies of Volume I. in paper, and of Volumes V., VI., and VII. in paper or cloth, will be mailed to members on receipt of 75 cents for paper covered, and $1.00 for cloth bound copies. The corresponding prices for Volumes VIII, IX or X, are $1.00 for paper and $1.25 for cloth bound copies.

A few copies of single papers unbound will be carried. These can be purchased by members at a rate of 1 cent a page, no paper to cost less than 10 cents.

In order to keep the cost of publication of papers within the limits of the resources of the Society, the Board desires to impress on all authors the necessity of restricting their illustrations to single page and to a limit of three pages. The Board reserves the right of supervision of papers and illustrations.

In regard to preparing drawings for publications: Tracings only can be used, and these must be in strong lines and strong lettering. The author must make all tracings subject to reduction to 6½ inches in one dimension. The size of a single page of our publications is 6½x4 inches. Pull outs may be in multiples of the 4-inch dimension, but must not exceed 6½ inches in the other. Many tracings may be made so strong by using black ink and wide lines that reduction is possible across the page. All tracings can be reduced six to one. [Before any illustrations are reproduced the author must submit his tracings to the Board of Direction.]

TABLE OF STEEL REQUIREMENTS FROM VARIOUS SPECIFICATIONS FOR BRIDGES. OCTOBER, 1892

TABLE 'A'

Compiled by Harry J. Lewis

NAME OF SPECIFICATION		ULTIMATE STRENGTH	ELASTIC LIMIT	ELONGATION	REDUCTION	FRACTURE	FULL SIZED MEMBERS ULT STR	ELAS LIMIT	ELONG	RED	PROCESS.	CHEMICAL REQUIREMENTS PHOS	MISCELLANEOUS	BENDING	DRIFTING	REAMING OF PUNCHED HOLES
ATLANTIC COAST LINE		60 to 68000	34000	20% in 8"	40%		60 to 68000	34000	14% [illegible]	40%	ANY	008		180° FLAT		YES.
ATCHISON TOPEKA & SANTA FE	COMPRESSION	75 to 85000	40000	18% in 12 diam	35%									180° W=1xT		YES
	TENSION	64 to 70000	36000	25% in 12 diam	42%									180° FLAT		
	SUB. FOR IRON	55 to 65000	30000	25% in 12 diam	42%									180° FLAT		
BALTIMORE & OHIO	RIVETS & WEB PLS	54 to 60000	32000	26% in 8"	50%									RIV 0xT WEBS [illegible]		
	TENSION & PINS	60 to 66000	36000	22% in 8"	46%		58000	34000	10% in full length	40%				W=3xT		
	COMPRESSION	66 to 72000	40000	20% in 8"	40%									W=4xT		YES
BALTIMORE & OHIO SOUTHWEST RR		60 to 68000	1/2 ULT	20% in 8"	40%		60000	30000	16% in full length	40%	ANY.					
BOUSCARENS RR 1890		64 to 70000		26% in 12 diam			56000	33000	18% [illegible]			0.10		[illegible]		YES.
CINCINNATI NEW ORLEANS & TEXAS PAC.	CLASS 'A'	56 to 62000	33000	24% in 8"	50%		75% of specimen	85% of specimen			ANY	[illegible]		180° FLAT		YES
	CLASS 'B'	62 to 70000	35000	22% in 8"	46%		-	-			ANY	[illegible]		180° FLAT.		YES
CHICAGO BURLINGTON & QUINCY	EYEBARS	60 to 66000	34000	20% in 8"	36%		54000	32000	[illegible]	25%	OPEN HEARTH			FLAT	7/8" to 1½"	
CHESAPEAKE & OHIO	MEDIUM	60 to 68000	35000	20% in 8"			66000		21%					W=4xT		YES.
	SOFT.	52 to 60000	30000	26% in 8"			52000		16%					180° FLAT		
CENTRAL RR & BANKING CO OF GA	COMPRESSION	66 to 74000	1/2 ULT	20% in 8"	30%	FINE GRAINED BLUE GRAY						[illegible]		W=3xT	1½" from edge 20%	YES.
	TENSION	62 to 68000	- -	- -	-	- -	60000	30000				[illegible]		- -	- - - -	
	ROLLED BEAMS	57 to 65000	- -	- -	-	- -						[illegible]		- -	- - - -	
COOPERS RR 1890	MEDIUM	62 to 68000	35000	20% in 8"		BLUE STEEL GRAY					ANY			W=3xT		YES.
	SOFT	54 to 62000	30000	25% in 8"							-			180° W=2xT		NO.
GREAT NORTHERN RY.	-	60 to 68000	36000	[illegible] in 8"	[illegible]							[illegible]		180° W=3xT [illegible]	24%	YES
ILLINOIS CENTRAL	COMPRESSION	75 to 85000	40000	18% in 12 diam	30%									W=1xT		YES
	EYEBARS & PINS	64 to 72000	37000	20%	42%									W=0 FLAT		
	SUB FOR IRON	54 to 62000	30000	26%	50%											
LOUISVILLE & NASHVILLE JAN 1st 1890	COMPRESSION	66 to 74000	1/2 ULT	20% in 8"	30%	BLUE GRAY					OPEN HEARTH			W=1xT	25%	YES
	TENSION	60 to 68000	.	. .	.	. .	60000	30000	12½%		. .			.	.	
	ROLLED BEAMS	57 to 65000	.	. .	.	. .					. .			. .	.	
LAKE SHORE & MICHIGAN SOUTHERN		54 to 62000	30000	25% in 8"	45%						ANY	[illegible]			1¼ DIAM of HOLE	[illegible]
MICHIGAN CENTRAL		54 to 60000	55% of ULT	25% in 8"										180° W=1xT	20%	
NEW YORK CENTRAL		58 to 65000	35000	[illegible]							OPEN HEARTH	[illegible]	[illegible]	180° FLAT		[illegible]
NEW YORK & NEW ENGLAND 1892	TENSION	62 to 70000	36000	[illegible] %	[illegible]	BLUE STEEL GRAY						010		FLAT		
	COMPRESSION	70 to 80000	42000	-	-	- -						010		FLAT		YES
NEW YORK PROVIDENCE & BOSTON	COMPRESSION	65 to 70000	1/2 of ULT	[illegible] in 8"	[illegible] %									FLAT		YES
	TENSION	60 to 65000	- - -	-	-									-		
	RIVETS	55 to 60000	- - -	-	-											
NORFOLK & WESTERN JAN 1st 1890		60 to 70000	35000	22% in 8"	40%	SILKY DUCTILE	65000	33000	18%					180° FLAT	[illegible]	YES
NORTHERN PACIFIC		60 to 68000	1/2 of ULT	[illegible]	[illegible]		56000					[illegible]		FLAT		YES.
PENNA LINES WEST OF PITTSBURG	3/4" ROUND	62 to 70000	1/2 MAX	20% in 8"	50%		64000	30000	10%		ANY.	008		180° FLAT		YES
	SPECIMEN	60 to 68000	1/2 MAX	20% in 8"	45%									- - -		-
RICHMOND & DANVILLE	EYEBARS & PINS	62 to 70000	32000	22% in 8"	45%		58000		12%		ANY	008		180° FLAT		
UNION PACIFIC	SOFT	54 to 62000	30000	25% in 8"		FINE GRAINED BLUE STEEL GRAY					ANY			W=2xT		
	MEDIUM	62 to 68000	33000	20% in 8"		- -					-			W=3xT		YES
WABASH RR CO	EYEBARS	60 to 68000	1/2 of ULT	[illegible] in 8"	[illegible] %		35% [illegible]		[illegible]	[illegible]	ANY			W=2xT		
CITY OF COLUMBUS, OHIO		54 to 62000	1/2 ULT	25% in 8"	50%						OPEN HEARTH	[illegible]		180° FLAT	[illegible]	

Hearth furnace and the Bessemer converter, marks an epoch in the metal trade which has long been predicted. This change is already so complete that it is almost impossible to obtain puddled iron of good quality and satisfactory pedigree, except for some special uses where it has held its own against the product of the furnace and converter. Shape rolls have also been adapted to the working of steel, and will hardly do satisfactory work in iron, even when the material is at hand.

Steel scrap has become so common that it is very difficult to exclude it entirely from the piles for muck bar, no matter how careful the mill management may be, and instances are not lacking where it has been added deliberately for the purpose of raising the tensile strength of the so-called iron. While an apparently good weld can be made in some steel, it is equally true that it cannot be done at all times and in all steel, which fact puts the shadow of a serious doubt on all material whose quality depends upon the perfect welding of the motley collection of steel and iron which may at present find its way into a muck bar. Common sense would, therefore, seem to dictate that if we must use steel—and it now seems inevitable—we should take it as soon after it leaves the melting pot as possible, at the same time demanding such knowledge of the physical and chemical properties of each blow or melt as will insure both homogeneity and good quality.

These notes are not written for the benefit of those who must have special designs and special materials for the construction of engineering monuments which fail to pay interest on the investment, but for a more modest and happily more numerous class of engineers who are contented to submerge their ambitions and build from simple and well-tried standard designs with the best material to be obtained in the competition of the open market. This competition, together with intelligent specifications and inspection by the purchaser, is continually leading to the improvement of material, and during the past few years progress has been so rapid and has skipped from

one method to another in such a way that standard specifications have in many cases been left behind in the actual execution of work. The object in writing this is, therefore, to reflect as far as possible the present state of the steel-making industry as regards bridge material.

The first experiments in the use of steel in bridge work were mainly with material having an ultimate strength of 60,000 lbs. to 68,000 lbs., and in some cases from 70,000 lbs. to 80,000 lbs. Its irregularity in physical properties, together with the extra shop-work in the way of reaming rivet holes, etc., furnished a decided obstacle to its use in spans of moderate length, not only for the reason that the added cost of manufacture more than offset the saving in weight, but because conservative designers were slow to advance unit strains in proportion to the differences between the ultimate strength of this material and iron. For this reason, therefore, the use of medium and hard steels has been confined mainly to long spans, where the reduction of dead weight, consequent upon increased unit strains, effects almost double economy, and to eyebars, which in annealing become practically a soft steel. On the contrary, in short spans (up to 250 or 300 feet) there is no special desire to reduce dead weight unless attended by corresponding reduction in cost, as the dead weight is considered to be an element in the steadiness of the structure, and in these iron held its own for some time.

Of late, however, there has been a very decided movement in favor of soft steel, partly on account of the difficulty in obtaining iron, and which has resulted in the almost complete displacement of the latter material in bridge work. As might be supposed, the principal reason for this driving out of iron by steel is a purely commercial one, the fact being that the cost of iron made entirely from fresh-puddled stock is above that of steel which will stand much more severe physical tests.

The specifications appended below are suggested as covering most of the essential points of a good soft steel, and under

practically the same requirements some very satisfactory material has already been obtained. It will be noted that they are somewhat brief, but experience has shown that short specifications are more likely to be lived up to, both by the inspectors and the mills, than long ones burdened with many comparatively unimportant details. At the same time, sufficient tests of different kinds should be required to place the quality of the material beyond any reasonable doubt, and that has been aimed at here. No new features have been introduced, however, as the mills are somewhat shy of accepting orders accompanied by specifications containing unusual requirements without making an advance in price which is very often entirely out of proportion to the advantages gained, and these specifications are intended to aid those who desire to obtain a good material at little or no advance from market rates.

The interests of the buyer and seller are in many things mutual as long as there is a disposition on both sides to play fair, and a good specification well lived up to benefits the honest manufacturer as well as his customer, the former being protected from the competition of shysters and the latter securing a uniformly good material. In this connection attention is also called to the fact that if a more uniform set of requirements were adopted the mills would find their work much simplified, and thus be able to cheapen their product. For instance, as at present, when the rolls are put in for a certain shape they may have to provide at least three different kinds of billets or blooms of soft, medium and hard steel, and roll extra pieces of each kind to provide for imperfections and rejections, much of which would be avoided by more uniform requirements, and the reduced amount of material thrown into stock would result in economy to the buyer. The stock itself would also become more valuable on account of its greater uniformity.

SPECIFICATIONS.

1. All steel shall be made by the Open Hearth process.

If made by the acid process it shall not contain more than 0.08 of one per cent. of phosphorus, and if made by the basic process the phosphorus shall not exceed 0.04 of one per cent.

2. Two test pieces shall be furnished from the finished material of each melt, and in case more than one section is rolled from a melt, a single test piece shall be furnished from each. These test pieces shall have an area of cross section not less than one-half square inch, nor greater than one square inch.

3. When the first two specimen tests fail to fill the requirements of these specifications, the whole melt shall be rejected and additional tests will not be allowed, except in case of obvious local defects in the original specimens.

4. Test pieces as above shall give results as per the following table:

Ultimate strength 54,000 lbs. to 62,000 lbs. per sq. in.

Elastic limit not less than one-half ultimate strength.

Elongation not less than 26 per cent. in eight inches.

Reduction of area at fracture, 50 per cent.

5. A copy of the analysis of each melt shall be furnished giving percentages of carbon, phosphorus, manganese and sulphur. The melt number shall be clearly stamped on each piece of material rolled, and failure to render all material easy of identification may furnish cause for rejection.

6. All fractures shall be fine, silky grey and entirely free from crystalline appearance.

7. Specimens shall bend double under the hammer, cold, without showing signs of cracking; and a punched hole three-fourths of an inch in diameter and 1½ inches from center to planed or rolled edge, must stand drifting to twice its original diameter without signs of cracking or failure either on the inside of the hole or edge of piece.

8. All finished material shall be free from cracks, blisters, scale or cinder spots, and have clean edges and good surface free from buckles or short bends.

9. Specimen tests of steel for eye-bars shall show an

TABLE OF STEEL REQUIREMENTS FROM VARIOUS BRIDGE SPECIFICATIONS

REVISED TO SEP 1st 1894

Compiled by Harry J. Lewis

TABLE 'B'

NAME OF SPECIFICATION	CLASSIFICATION OF MATERIAL	ULTIMATE STRENGTH	ELASTIC LIMIT	ELONGATION	REDUCTION	FRACTURE	FULL SIZE MEMBERS: ULT STR	FULL SIZE MEMBERS: EL LIM	FULL SIZE MEMBERS: ELONG	FULL SIZE MEMBERS: RED	PROCESS	CHEMICAL REQUIREMENTS: PHOS	CHEMICAL REQUIREMENTS: MISCELLANEOUS	BENDING	DRIFTING	REAMING OF PUNCHED HOLES	
ATLANTIC COAST LINE		60 to 68000	34000	20% in 8'	40%		60 to 68000	34000	[illegible]	40%	ANY	008		180° FLAT			
ATCHISON TOPEKA & SANTA FE R.R.	COMPRESSION	75 to 85000	40000	18% in 12 diam	35%									180° W=1·t		YES	
	TENSION	60 to 70000	35000	23% - - -	42%									180° FLAT			
	[illegible]	55 to 65000	30000	23% - -	42%									180° FLAT		NO	
BALTIMORE & OHIO RR EDITION 1894	MEDIUM	60 to 68000	½ ULT	20% in 8' [illegible]		[illegible]	58000	½ ULT	[illegible]		OPEN HEARTH	[illegible]		[illegible]	[illegible]	YES.	
	SOFT	52 to 60000	½ ULT	25% in 8'		[illegible]					- -	[illegible]		[illegible]	- -	[illegible]	
BALTIMORE & OHIO SOUTHWESTERN RR EDITION 1894	[illegible]	60 to 70000	34000	23% in 8	43%	CLEAR SILKY GREY	58000	31000	[illegible]	40%	ANY	[illegible]	[illegible]	180° W=1½t		YES	[illegible]
	[illegible]	54 to 62000	33000	25% in 8'	50%	CLEAR SILKY						[illegible]	[illegible]	180° FLAT		[illegible]	[illegible]
BOUSCAREN'S R R 1890		64 to 70000		20% in 12 diam			56000	33000	[illegible]			010		[illegible]		YES	
CINCINNATI NEW ORLEANS & TEXAS PAC		56 to 62000	33000	25% in 8"	50%		[illegible]	[illegible]			ANY	0075		180° FLAT		YES.	[illegible]
CHICAGO BURLINGTON & QUINCY R.R.	EYEBARS.	58 to 66000	34000	20% in 8'	40%		54 to 62000	32000	[illegible]	30%	OPEN HEARTH			180° W=t		YES	
CHESAPEAKE & OHIO RY.	MEDIUM	60 to 68000	35000	20% in 8"			55000		12½%					W=1½t		YES	
	SOFT.	52 to 60000	30000	25% in 8"			52000		18%					180° FLAT			
CENTRAL RR & BANKING CO OF GA	COMPRESSION	66 to 74000	½ ULT.	20% in 8'	30%	FINE GRAINED BLUE GRAY						[illegible]		W=3·t	1½ [illegible] 25%	YES	
	TENSION.	62 to 68000	-	- -	-	- -	60000	30000	12½%			- -		- -			
	ROLLED BEAMS	57 to 65000	-	- -	-	- -						- -		- -			
COOPER'S R R 1890	MEDIUM	62 to 68000	35000	20% in 8'		BLUE STEEL GRAY					ANY.			W=3·t		YES	
	SOFT.	54 to 62000	30000	25% in 8'							-			180° W=2·t		NO	
CLEVELAND, CINCINNATI, CHICAGO & ST LOUIS	[illegible]	60 to 70000	36000	23% in 8'	43%	CLEAR SILKY GREY	60000	34000	[illegible]	40%	ANY.	[illegible]	[illegible]	[illegible] 180° FLAT.		YES.	[illegible]
	[illegible]	54 to 62000	33000	25% in 8'	50%	CLEAN SILKY					ANY	[illegible]	[illegible]	[illegible] 180° FLAT.		[illegible]	[illegible]
GREAT NORTHERN RY.	MEDIUM	60 to 68000	36000	22% in 8'	44%		[illegible]	[illegible]			ANY	[illegible]		[illegible]	ORIG DIAM + 25%	YES	
	SOFT [illegible]	54 to 62000	34000	22% in 8"	44%												
ILLINOIS CENTRAL R R.	WEB PLATES.	54 to 62000	33000	28% in 8"	50%												
	FLANGES	60 to 68000	35000	20% in 8"	44%												
	RIVETS	54 to 62000	32000	28% in 8"	50%												
LOUISVILLE & NASHVILLE R R. JAN 1st 1890	COMPRESSION	66 to 74000	½ ULT	20% in 8"	30%	BLUE GRAY.					OPEN HEARTH			W=3·t	ORIG DIAM + 25%	YES.	
	[illegible]	60 to 68000	-	- -	-	- -	60000	30000	12½%		- -			- -	- - -		
	ROLLED BEAMS	57 to 65000	-	- -	-	- -					- -			- -	- - -		
	RIVETS.	52 to 60000	30000	25% in 8"													
LAKE SHORE & MICHIGAN SOUTHERN RY.		56 to 64000	60% ULT.	28% in 8"	45%	FINE SILKY BLUE GRAY	56000	60% ULT.	15%		OPEN HEARTH.	008		180° FLAT.	1½ TIMES [illegible]	[illegible]	
MICHIGAN CENTRAL R R	[illegible]	57 to 65000	55% ULT.	[illegible] in 8"	45%	SILKY	54 to 60000	55% ULT	[illegible]	40%	OPEN HEARTH	008		180° FLAT		[illegible]	
	RIVETS.	50 to 60000	- -	27% in 8	50%	-					- -	-		- -			
NEW YORK CENTRAL & HUDSON RIVER RR		58 to 65000	38000	[illegible]	56%						OPEN HEARTH.	[illegible]	[illegible]	180° FLAT		[illegible]	[illegible]
NEW YORK & NEW ENGLAND R R	TENSION	62 to 70000	36000	[illegible] %	[illegible] %	BLUE STEEL GRAY						010		FLAT.			
	COMPRESSION	70 to 80000	42000	-	-	- - -						010		-		YES.	
NEW YORK, NEW HAVEN & HARTFORD, RR OLD COLONY SYSTEM.	COMPRESSION	66 to 70000	0.6 ULT.	[illegible] % in 8"	[illegible] %									FLAT		YES	
	TENSION	60 to 65000	- -	- -										-			
	RIVETS.	55 to 60000	- -	- -										-			
NORFOLK & WESTERN R.R. [illegible]		60 to 70000	35000	22% in 8"	40%	SILKY - DUCTILE	56000	33000	10%					180° FLAT.	[illegible]	YES	
NORTHERN PACIFIC R. R.	[illegible]	62 to 68000	0.6 ULT	[illegible] %	[illegible] %		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	180° W=4·t	¾ to 1½ DIAM	YES	
	[illegible]	56 to 62000	- -	-	-		[illegible]	- -	-		OPEN HEARTH			180° W=4·t [illegible]	¾ to 1½ DIAM		
PENNA LINES, WEST OF PITTSBURG, SOUTH WEST SYSTEM.	[illegible]	62 to 70000	½ MAX [illegible]	20% in 8"	45%						OPEN HEARTH	008		180° FLAT		YES	
	[illegible]	60 to 68000	-	20% in 8"	43%		54000	30000	10%		- -	-		- -			
PENNSYLVANIA RAILROAD.	EYEBARS	62 to 65000	½ ULT.	26% in 8"		[illegible]	47000		[illegible]		OPEN HEARTH	008		180° W=t			
SOUTHERN RAILWAY CO EASTERN SYSTEM	[illegible]	60 to 68000	35000	22% in 8'	40%		58000	32000	[illegible]	40%		008		180° W=t			
	[illegible]	62 to 70000	34000	20% in 8'	40%							[illegible]		180° W=t		YES	
	[illegible]	54 to 62000	30000	25% in 8	40%							[illegible]		[illegible] 180° FLAT	[illegible]	NO.	[illegible]
UNION PACIFIC RY.	MEDIUM	60 to 68000	35000	25% in 8'	45%	[illegible]					ANY			W=3·t		YES	
	SOFT	54 to 62000	33000	25% in 8'	50%	- - -					-			W=2·t			
WABASH R.R	EYEBARS.	60 to 68000	0.6 ULT.	[illegible] % in 8"	[illegible] %		[illegible]		[illegible]	[illegible]	ANY			W=2·t			
CITY OF COLUMBUS, OHIO		54 to 62000	½ ULT	26% in 8'	50%						OPEN HEARTH	[illegible]		180° FLAT	[illegible]		

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ultimate strength of 57,000 lbs. to 65,000 lbs. Elastic limit, one-half ultimate strength; Elongation, 25 per cent. in 8 inches; Reduction, 45 per cent. Full sized tests of annealed eye-bars shall show an ultimate strength of 54,000 lbs. to 62,-000 lbs. Elastic limit, one-half ultimate; Elongation, 18 per cent. in 10 feet, including fracture; Reduction, 45 per cent.

10. All rivets in steel work shall be steel of the softest grade, capable of bending double and upsetting to one-third of original dimensions, cold or hot, without the least sign of cracking.

The limitation to the Open Hearth process has been and will be hotly contested by the makers of Bessemer stock, and a few of them can undoubtedly point to good results; but the fact remains, that while nearly all the makers of Open Hearth can turn out a fairly uniform quality of soft steel, only a small proportion of the soft Bessemer shows such uniform ductility, while in punching, hard and soft spots are often found to alternate each other at intervals of a few feet only. Including both the acid and basic processes, there are now enough works producing Open Hearth steel to insure plenty of competition, with consequent low prices, and this specification has therefore been written to cover both, there being at present but little preference between them as to quality. A different phosphorus requirement is given for basic and acid steel for the reason that an amount of phosphorus in basic stock equal to that which acid stock might carry with safety, would indicate that something was radically wrong with the melt in which it occurred, and should alone furnish grounds for rejection. These remarks should not be construed as casting any reflection on the record which the Bessemer process has made for itself in the production of medium steel, to which grade it seems to be equally as well adapted as the Open Hearth.

The clause requiring two test pieces from each melt is intended to avoid delay for both mill and inspector in cases where second test is found necessary, and the requirement cov-

ering a test piece for each section rolled from a melt, is for the purpose of developing any differences caused by heating or rolling. The range allowed in area of cross section is sufficient to cover a wide range of sections, and at the same time is intended to exclude any large differences of physical characteristics depending on the flow of the material in the tensile test.

The ultimate strength has been placed at 54,000 to 62,000 lbs. so as to fully justify an increase of 10 per cent. over allowed unit strains for iron, and it is found in practice that a very small percentage of material falls below 55,000 lbs. Experience would indicate that it is not safe to use the medium strength of 58,000 lbs. in determining allowed unit strains, as the average of a day's tests will often fall as low as 56,500 to 57,000 lbs. The upper limit of 62,000 lbs., is also low enough, when taken in connection with the other requirements, to exclude any metal which would receive or retain temper or fail to close up, in rolling, any small imperfections in the ingot. Practice has also demonstrated that the 8,000 lbs. range allowed between upper and lower limit is ample, there being virtually no rejections on this score except such as are due to accident or carelessness in one or more of the four stages of production, viz:—the furnace charge; the melting; the heating of the ingot and reheating of billet, bloom or slab; and the rolling.

The elastic limit has been placed at one-half the ultimate strength, which is somewhat low, in order to remove as far as possible any incentive to cold rolling, and this has not been found to result in any lowering of the quality of the material. The different ways of obtaining the elastic limit in the various mills make this the most uncertain of all the observed properties of the material, and it is therefore hardly advisable to make the requirements regarding it too rigid, except in special cases, when the mode of taking the observation should be definitely prescribed.

The elongation has been fixed at 26 per cent. in 8 inches, as that figure seems to practically exclude all material showing

the dry, dark, open-grained fracture so hard to describe, and yet so easy to recognize, and which is probably caused in most cases by improper heating. It has also been found that material showing the above elongation would pass the bending and drifting tests almost or quite invariably.

The reduction of area at fracture is placed at 50 per cent., as the result of a considerable number of tests would indicate that this figure corresponds with moderate closeness to the minimum percentage of elongation above noted, where no apparent flaw exists at the point of fracture. The object has been to bring the two measures of the ductility of the material as nearly into harmony as possible. Some writers of specifications have omitted to require a record of the reduction of area, but in spite of the fact that it is only an approximation, the figures are so easy to obtain, and tell such a story as to the uniformity of the material that they they should not be neglected.

A sliding scale has been adopted by some making the percentage of elongation equal 2,800,000, divided by the ultimate strength, and the reduction equal 1,500,000, divided by the ultimate strength, as in the accompanying table. This scheme has been rejected in writing the above specifications, as it is intended to secure a material equal to or superior to iron, and therefore a high degree of ductility is required at the upper as well as the lower limit of ultimate strength. It is desired to shut out in this way rejected melts of medium steel, which are too stiff to be classed as strictly soft steel.

No definite requirements have been made as to chemical composition except for phosphorus, as it is not desired to hamper the manufacturer further than necessary. It is considered advisable, however, to require a record of analyses showing percentages of carbon, phosphorus manganese and sulphur, in order to determine whether each individual manu facturer is turning out a fairly uniform product.

While the character of the fracture alone could hardly be

considered in itself as sufficient ground for rejection, a bad fracture should always cause a rigid investigation of the melt from which it is obtained.

The bending and drifting tests are required, as through them the high degree of ductility which it is desired to secure, under all classes of strains, is more fully assured. That they are not too severe has been amply demonstrated in practice.

The clause relating to material for soft steel eye-bars is not based on a sufficient number of tests to justify its unqualified recommendation. Such work as has been done, however, would indicate that soft basic steel suffers a greater reduction of ultimate strength between test specimen and annealed full size member than medium steel; the observed differences averaging about 6,000 lbs., as against 4,000 for the latter. If further observations show this to be a constant characteristic, it may be found advisable to increase the range between the upper limit of ultimate strength in the specimen test, and the minimum limit of the annealed full-sized test, in which case it would probably be better to lower the latter requirement to 52,000 lbs. than to increase the former. In the absence of sufficient data from soft steel eye-bars this inference has been drawn, from the experience of railroad boiler makers, who have found 65,000 lbs. to be about the right upper limit for material which is to be worked with perfect safety in the blacksmith's fire, and the operation of flanging a boiler-head is certainly no more severe a test of the forging qualities than the upsetting of an eye-bar head.

A strictly soft steel eye-bar is advocated because these, of all members of a bridge, are the ones which must be good or else irrevocably bad. A small transverse crack, for instance, which would ruin an eye-bar eventually, might not cause any difficulty whatever in a compression member, as the character of the work performed by the tension member has a continual tendency to increase the defect, while the strain in the latter tends continually to press the sides of the crack closer together. Again

while the compression member is being continually favored by the use of formulæ for the reduction of allowed unit strain, the eye-bar receives no allowance whatever, and its unit strains are invariably much higher, which also adds to its chances of failure from flaws. The stiffness of the higher steels under strain is a serious objection to their use as tension members, where the unavoidable inaccuracies of workmanship and other causes subject them to strains which demand material of the highest possible ductility. Soft steel certainly possesses this quality in the highest degree, and therefore presents superior claims to be used in eye-bars. It is an axiom in railroad management that no company is doing its full duty unless it uses the best material to be obtained in the market, and careful consideration will show that soft steel presents very strong claims to this distinction, especially as eye-bar material.

No limit has been set on the thickness of material which may be punched, as it has not as yet been proved that good soft steel suffers any more injury than iron in punching, and late experiments would suggest that drilling or reaming injures it nearly as much as punching. It is not feasible in soft steel to punch holes whose diameter is less than the thickness of the material, as the punches will not stand it, except for a few holes in some exceptional cases, and no intelligent designer would think of requiring it, where it could be avoided. Such experiments as have been made would seem to indicate that there is no great injury either to iron or steel until the above limit has been reached, and where any considerable number of holes are required in thick material, it is probably even cheaper to drill them.

In the long span plate girders, which are becoming so common, there is often a strong temptation to use a thick flange angle in order to reduce as much as possible the percentage of area in the flange plates, and indeed some specifications make an especial point of requiring the maximum thickness of angles. It is undoubtedly bad design to carry this so

far as to put the material in danger of injury from punching, and it should always be avoided, even if a little larger percentage of section does find its way into the flange plates. A simple and much more effective remedy would be the production of 8x8 in. or 9x9 in. angles, which would allow three lines of rivets and increase the width of the flange plates at the same time. Rolls are now maintained by the mills for a much smaller tonnage than would be required from these as soon as designers found they could be obtained. [Since writing the above information has been received that at least one mill is ready to make angles of one or other of these sizes.]

The appended tables, "A" and "B," represent about two years' progress. Table "A" was prepared from information received during October of 1892, while table "B" is intended to be revised to September 1st, 1894. A careful comparison of information received at these two times shows three things very clearly, viz :

First. That some specifications, which at the time of the first table did not recognize steel at all, are now the most explicit in their requirements.

Second. That one road has adopted soft steel and abandoned medium steel since the first table, while others have in the meantime added soft steel to their specifications ; and one road which had already adopted it has in the meantime seen its way clear to raise its requirements for ductility considerably, at the same time raising the ultimate strength by 2,000 lbs.

Third. That there is a decided movement in favor of the Open Hearth process, table "B" showing nine roads which require it exclusively as against three in table "A."

The President—I would like to ask Mr. Lewis for some information as to the data and experiments on which he decides that soft steel does not need reaming in the rivet holes.

Mr. Harry J. Lewis—I had some experiments made with the intention of trying to develop in punched material strains which would be equal to, or even more severe than they

would ever receive in actual service. In order to do this, I had some strips prepared (all from the same plate) about two inches wide, and one was pulled in a testing machine plain, without any punching, and another was punched in the middle and pulled as standards for comparison; another was punched and bent to an angle of about forty degrees from a straight line and bent back, and another was placed in a vise and the free end beyond the punched hole bent back and forth about twenty degrees from a straight line twenty times, without sign of cracking at the hole in either specimen. These pieces were then pulled, and the ultimate strength and elastic limit of the net section across the hole were very close to that of the standard specimens. This was all soft steel, prepared on these specifications. The tendency of the work done on the specimens seemed to be toward an increase of the ultimate strength and a corresponding reduction in ductility. This is also true of other operations, such as cold rolling and wire drawing, and is probably a manifestation of the principle of the conservation of energy.

THE PRESIDENT—Mr. Swensson, have you anything to say?

MR. EMIL SWENSSON—I can hardly say anything in addition to that which has already been said in the paper, because I fully coincide with Mr. Lewis on these points, being a "soft steel crank" myself, but possibly I can add a little by calling your attention to the principal reason for the demands for soft steel, and preferably Basic Open Hearth Steel, in bridges, which are being constructed at the present time.

The engineers have simply been driven into it by the constantly increasing rapidity in the processes of steel making.

There was a time—say 15 years ago—not even that long, perhaps, when Bessemer steel of medium and even higher grade was very good and suitable for structural work. In looking up some tests of annealed eye-bars made about twelve years ago of Bessemer steel, I found they showed 70,000

pounds ultimate strength, 40,000 pounds elastic limit, an elongation of 20 per cent and a reduction of 50 per cent. We cannot very well demand better results from an eye-bar, but such Bessemer steel is not easily obtained to-day.

In those days they made a melt about every forty minutes, and now they make three melts in thirty minutes, say a melt in ten or twelve minutes. This it is that has driven us to open hearth steel, and finally to soft steel, and I would not be surprised if we would be driven still further. I think the ideal for steel will finally be to use it the same as iron and get it down to iron limits, using it the same as iron in all respects.

However, when we get down to very soft steel we must become very guarded on the phosphorus question, particularly in basic open hearth steel, because in the softening process the phosphorus is liable to remain as in the ordinary soft steel and the carbon reduced to such an extent that the steel becomes what is commonly called rotten. In other words, all the hardening ingredients should be reduced in proportion when we want to obtain the softest steel.

Of course, when it comes to long spans higher steel should be used to reduce the dead weight of structure, and we can get just as uniform high steel, I think, as we can low made by either process if only the manufacturers can be induced to work a little slower.

Mr. James M. Camp—I am opposed to this wholesale condemnation of Bessemer steel; I have a very friendly feeling for it. I think that so far as the phosphorus, sulphur, and carbon contents of Bessemer and open hearth steels are concerned the engineer cannot tell the difference. I know that in the laboratory we cannot, and I fail to see how they can.

In his paper Mr. Lewis stipulates that a copy of the analyses of each melt shall be furnished, giving percentages of carbon, phosphorus, manganese, and sulphur, and then requires certain physical conditions as ultimate strength, reduction of area and elongation, etc. These requirements are met in

the variations of the chemical contents of the steel, and if you have one you have both. How the physical requirements are met chemically I cannot see is any concern of the engineer.

Mr. Lewis—Replying to Mr. Camp's inquiry as to why Bessemer steel is excluded I would state that in addition to the lack of uniformity noted in my paper we find in it a tendency to break under slight provocation, particularly into or through a punched hole, the fracture showing a texture similar to cast iron. My experience is that these breaks will and do occur in material which, according to the testing machine and cold bending test, is a soft ductile steel. I have never yet traced any similar trouble to a good soft open hearth steel, and therefore place a degree of confidence in it which I cannot feel for Bessemer steel.

I have never seen any snap through a punched hole that could be traced to open hearth stock, and I have seen plenty of it. As regards the chemical analysis it must be valuable, or the steel maker would not go to the trouble and expense of obtaining it, and if he be honest he will not have any object in withholding it from his customer.

Mr. Swensson—In regard to chemical analyses I would like to remind Mr. Camp that a relative proportion of ingredients is very important to the material, and also that if he would only spend a day or two at a punching machine he could soon learn which is Bessemer and which is open hearth steel.

Mr. Camp—The gentlemen forget that they are comparing ordinary .10 phosphorus Bessemer with open hearth, which will show phosphorus .04 per cent or under. It should be a comparison of like steels chemically all the way through.

Mr. Lewis—In this paper the basis of like steels is the price per pound, and I am endeavoring to aid my brother engineers in selecting the good and excluding the bad from such material as can be obtained at a reasonable price.

Mr. M. J. Becker—There was one piece of news related

by Mr. Lewis that rather pleased me, and that is the announcement that some rolling mills are starting to make angles with 8″ legs. I think that is a great step forward.

Now, we all know that (especially in track stringers and floor beams) with moderate-sized angles the necessity arises of piling on cover plates; and whenever we can get sufficient sectional area in the flange angles, a large amount of labor is not only saved, but the whole structure considerably improved. This will also apply in a great measure to all plate girder bridges.

We have found that much of the trouble experienced in our plate girder bridges is due to the small angles which we had to employ in the earlier days because we could not procure any larger ones, and whenever the area was anyways large it would be made up by piling on and piling on cover plates, and the next thing was to drive the little thin rivets through these successive layers of metal.

I have seen some of these old bridges planed through the rivet holes, and the rivets looked more like corkscrews than anything else. I would like to see the size of the legs of angles increased just as much as the machine will stand.

It seems to me that at the meeting of the American Society at Seabright, some four or five years ago, there was exhibited a large lot of riveted plate steel in part of which the rivet holes had been punched and riveted; others punched, reamed and riveted, and some had been drilled only. The result showed very decidedly, upon application of the tensile test, that the punched and reamed arrangement was by all odds the most satisfactory—better than either the drilled or punched. I think the test was made in the Pencoyd establishment, and there was a paper written on the subject at that time.

Mr. Lewis—My impression is that those tests were made with steel which should be classed as medium, rather than soft. As regards soft steel, the experiments of a friend of mine, whose paper on the subject I do not wish to anticipate, would

indicate that the extreme toughness of good, soft steel is a drawback, rather than an advantage, when it comes to reaming or drilling. The material seems to drag round after the tool, and does not take a good, clean cut, thereby receiving around and outside of the hole more injury than would be inflicted by a punch and die in good condition. My own experience last summer, in trying to obtain a clean finish on some large, soft steel bridge pins, would confirm this idea as to the difficulty of obtaining smooth machine work.

Mr. Swensson—In regard to punching and reaming, I would like to say a word for the manufacturer. I think, if any engineer specifies the reaming of medium steel, he should also allow increased unit strains for rivets.

Going back to Mr. Lewis' paper, I think it well to take exception to his remark about the annealed eye-bar. He would like to run down to 52,000 in the full-size test. In my judgment, it should not run any lower than his specifications of 54,000 for other parts of the structure. If you lower one you should lower it for the other parts.

Mr. Camp—In blowing steel or burning out the impurities, carbon and silicon, if the operation is carried too far, the bath will be charged with considerable oxide of iron, and the addition of the ferro-manganese afterward will fail to take up these oxides, and the result is a steel such as Mr. Swensson speaks of; it acts like steel high in sulphur.

It rarely happens that such heats escape the blowers, and if it slips them it shows in rolling, and lastly it is not likely to get through the laboratory. These three tests generally lay it on the scrap pile where it belongs.

The President—Mr. Swensson, a few minutes ago, made some remarks in regard to annealing eye-bars, and the ultimate strength of annealed eye bars.

In this connection I would like to call attention to the fact that there is a difference in strength between the full sized and

test specimens due to the size and shape of the section, and not to the question as to whether it is annealed or not.

Some years ago the formula was first advanced reducing the allowed ultimate strength in the full sized test in proportion to the ratio of the area of the section to the perimeter, and in order to satisfy myself as to whether that was based on correct principles or not, I platted a large number of the tests which appeared in our inspectors' reports; I do not know how many tests exactly, but there were several hundred. The specimen tests cut from the bars showed a uniform average ultimate, and elastic limit for all sections of bars, without any tendency at all toward a depression of the line through the platted spots; while the tests of full size bars showed very decidedly a lowering of the ultimate and elastic limit as the ratio $\frac{A}{C}$ increased. The tests for iron and for steel were platted separately. The tests for steel which were then available were nearly all Bessemer, there being a few tests of open hearth among them, although I did not attempt to sort them out.

The average ultimate strength in iron full size test was represented by the equation $55,000—15,000\frac{A}{C}$, while the specimen tests averaged uniformly 52,000 lbs. per square inch for all sizes of original bar. There was a corresponding drop in the elastic limit in full size tests which would be represented by $34500—1150\frac{A}{C}$.

In the steel the full sized tests would be represented by $68000—13600\frac{A}{C}$, with the elastic limit at $41000—8250\frac{A}{C}$.

In platting the steel I included the reduction and elongation which had not been done with the iron, and found that in these results there was very slight evidence of a departure from the horizontal line; the reduction of area showing a slight

tendency to fall, along with the ultimate and the elastic limit, while the elongation showed a corresponding slight tendency to rise, with increased value of $\frac{A}{C}$.

Just how far these differences may be affected by annealing there is nothing in my researches to indicate, but I suppose the annealing must modify these results to some extent, more particularly in the elongation and reduction.

Mr. Swensson—It has been our experience that a bar of large sectional area will lose more in finishing than a bar of ordinary dimensions. Bars of 8" or 10" width usually lose about 6,000 pounds, instead of 4,000, in the full-size test, as compared with the specimen.

Mr. Becker—Does anybody know what the actual gain is by annealing, as against non-annealing? Have tests ever been made of an eye-bar not annealed, tested to destruction, and then taking a duplicate piece and making another test of it after being annealed, so that we may know something about what the actual effect of the annealing process is? I do not know as there is any such record in existence.

Mr. Swensson—In this connection, I would like to say that last summer I met in New York an English engineer named James, who said he was then in this country to introduce a process by which he could reduce the time of the basic open hearth process to one-half of that now required. I have not heard of it in Pittsburg as yet, but I expect we will learn a good deal when he comes around.

Mr. A. D. Wilkins—Mr. Lewis mentioned something about iron manufacturers rolling steel with their iron to increase the tensile strength. I would like to ask if he would reject merchant bar iron if he should discover steel rolled with it, provided the steel was not in too large section?

Mr. Lewis—That would depend, in the first place, a good deal on what I wanted it for, and before accepting it I would want to make some kind of a bending test which would develop

whether there was a lamination in welding between the steel and the iron. I would not accept it in any case if that lamination showed up in the bending test. If it did not, I might accept it.

Mr. Wilkins—There was one firm in this city which rolls steel with their iron, and I ran across some of it in my work, and as I had plenty of time to do so, I made some very interesting tests of that material.

I found that it would bend the same as ordinary iron will, and exhibited "barking," *i. e.*, the surface separates the same as iron, but if you examine the separated surfaces you will find that the iron is welded to the steel.

I made some very careful tests of that, and I am quite satisfied that the iron was welded to the steel, and that it is only the iron between the steel that separates.

(Here Mr. Wilkins related a test which he made not long ago with some 1″ bars of this material, in which the steel parts, when broken, always presented a silvery fracture without any indication of crystalization.)

Mr. J. C. Porter—I would like to have Mr. Lewis explain one thing here. I ask him this because I am not fully posted. He starts out as follows: "All steel shall be made by the open hearth process. If made by the acid process it shall not contain more than .08 of one per cent of phosphorus, and if made by the basic process the phosphorus shall not exceed .04 of one per cent," and a little further on he says "A different phosphorus requirement is given for basic and acid steel for the reason that an amount of phosphorus in basic stock equal to that which acid stock might carry with safety, would indicate that something was radically wrong with the melt in which it occurred, and should alone furnish grounds for rejection."

Now, I would like to know what those grounds for rejection are, and why one would not be as good as the other.

Mr. Lewis—I am not thoroughly posted myself, but I think the basic process depends for its success on the working of the basic lining of the furnace which absorbs the phosphorus from the metal and comparatively high phosphorus stock yields a low phosphorus product; the ordinary output running as low as from 0.006 to 0.035.

A higher figure than that given in my paper, viz., .04, would indicate that the basic lining is not working as it should.

Mr. Camp—That does not answer the question at all.

Mr. Porter—No, that does not answer my question. I want to know what that "something radically wrong" is.

Mr. Lewis—I endeavored to explain that when I said that it would indicate that the basic lining was not working properly, and there is no telling what might be wrong with the steel.

Mr. Wilkins—I do not know anything about the pig iron used by the basic steel manufacturers, but so far as the steel is concerned they do get the phosphorus down as low as .006 and .008. I have known of its being done both in Cleveland and here in Pittsburg.

Mr. Lewis—I would like to ask the President if he has gone on any further with his figures as to the relative influence of the different hardening elements in basic steel.

The President—What Mr. Lewis refers to was a paper offered before the mining engineers by William R. Webster, in which he analyzes the effect of different chemical constituents upon the ultimate strength of steel.

The material on which he was operating was Bessemer steel, and he deduced a series of constant co-efficients for each ingredient by which, having the chemical analysis, he could compute the ultimate strength within very close limits. I applied his figures to a test made on some Bessemer steel rails which ran up somewhere in the neighborhood of 50 carbon, with the result that the calculated strength very closely agreed with the results in the testing machine.

I have tried his formulæ with steel made in the open hearth furnace, and those constants will not apply at all. Why that difference should creep in I do not know. The constants developed for Bessemer steel do not apply to open hearth steel of the same chemical constituents.

Mr. White—He says he tried it on basic open hearth steel, and it did not work. Dr. Dudley got up a scheme of that kind, but I do not think he got very far; he tried to follow it up, but the combination was too strong.

Mr. Wilkins—I would like to ask the President whether the sample of open hearth steel was of the same chemical composition and in like physical condition as the samples from which the formulæ was calculated. Being finished a little cold at the rolls, or hammering sample to straighten it, would make considerable difference in the tensile strength.

The President—The test which agreed with Mr. Webster's formulæ was a Bessemer rail, high in carbon. The tests which did not agree were open hearth steel, but I do not recollect just what the grade of steel was. My object being to verify these constants as published in that paper, examples were taken at random from Inspectors' reports on file in the office.

A Member—What is the object in annealing an eye-bar; what good does it do to anneal it after it is made?

Mr. Lewis—As I understand it, the annealing is intended to remove as far as possible any unequal stress, particularly in the neck of the bar, where the heat tapers in forging from the working heat to the temperature of the bar outside the furnace.

Adjourned.

Daniel Carhart,
Secretary.

MEETING OF CHEMICAL SECTION.

ALLEGHENY, PA., March 15, 1895.

The regular meeting of the Chemical Section was held in the lecture room of the Carnegie Library Building on the above date.

Meeting called to order at 8 P. M by Chairman James M. Camp.

Minutes of last meeting read and approved.

The Committee on Chemical Literature reported abstracts of the following articles:

"Separation of Nickel from Iron by Potassium Xanthate," E. D. Campbell and W. H. Andrews in *American Chemical Journal* No. 3, 1895.

"Report of Committee on Atomic Weights," by F. W. Clark, in *Journal of American Chemical Society*, March, 1895.

"Separation of Zinc from Copper and Other Metals," H. W. Warren in *Chemical News*, February 22, 1895.

The Committee on Methods reported that they would soon send out letters on that subject.

Mr. A. G. McKenna then read the following paper:

BARIUM HYDRATE AS AN ABSORBENT IN CARBON DETERMINATIONS.

In the determination of carbon in iron or steel, potassium hydrate has been commonly used as an absorbent for the carbonic acid formed by combustion of the carbonaceous residue left after treatment of the metal by an appropriate solvent. In the somewhat similar determination of carbonic acid existing in the atmosphere barium hydrate has been almost universally employed as the absorbent. As the use of the latter absorbent offers some striking advantages over potassium hydrate, the Society may be interested in a number of experiments showing what precautions are necessary if barium hydrate is used in the combustion method.

The apparatus employed in all the experiments consisted

of a platinum combustion tube containing copper oxide and platinum gauze arranged as usual to insure complete oxidation of the carbon to carbonic acid with the customary means for purifying the current of oxygen and air from carbonic acid before entering the tube. The barium hydrate to absorb the products of the combustion was contained in an absorption tube consisting of a series of ten bulbs as shown in sketch.

In the first experiments the fixed carbon from a coke was used as a material for combustion. A known amount was weighed into a platinum boat which was then inserted into the tube. The absorption tube containing 100 c. c. of a solution of barium hydrate of known strength was next attached directly to the combustion tube through which a slow current of oxygen was forced. The burners were now lighted in the usual order and the combustion continued for fifteen minutes. At the end of which time the burners were extinguished, but the current of oxygen was continued for another fifteen minutes in order to sweep all carbonic acid into the absorption tube. The tube was now disconnected and its contents filtered into a flask, using a gentle suction so as to bring as little air as possible in contact with the solution. In washing it was found necessary to free the wash water from carbonic acid by boiling just previous to use. The filtrate in the flask was now titrated with standard sulphuric acid, using phenol-phtalein as an indicator. The end point is remarkably sharp and distinct. The sulphuric acid used was 1-20 normal, in which 1 c. c. =.0003 grams carbon. If the barium hydrate solution is also made 1-20 normal the difference between 100 c. c. and the number of cubic centimeters of sulphuric acid used in the titration multipied by .3 will give the milligrams of carbon in the sample.

If the barium hydrate is stronger or weaker it is simply necessary to substitute in the calculation for 100 c. c. the equivalent amount of barium hydrate used. The following results were obtained by the coke combustion :

Amount taken.	Amount found by titration.
.0077 grams.	.0075 grams.
.0256 "	.0250 "
.0298 "	.0290 "

Two grams of a steel containing 1.07 per cent. carbon were now dissolved in 150 c. c. of a 50 per cent. solution of copper potassium chloride containing 5 per cent. of concentrated hydrochloric acid. The solution was kept agitated for one hour at a gentle heat by means of a stirring apparatus. It was then allowed to remain quiet for several hours and filtered on asbestos in a platinum boat, washing with dilute hydrochloric acid, then hot water. The carbonaceous residue was burned without drying, exactly as the coke had been. The results were 1.11 and 1.12. As these these results are decidedly high (the results using potassium hydrate as an absorbent being 1.072 per cent., 1.068 per cent., 1.066 per cent., 1.070 per cent.) several combustions were made on sugar with the following results :

Amount taken.	Amount found by titration.
.0168 grams.	.0164 grams.
.0162 "	.0160 "
.0188 "	.0185 "
.0170 "	.0166 "

Another series of combustions on standard steels gave the following results, the barium carbonate precipitate being weighed after ignition as well as the solution titrated :

Found by potassium hydrate.	Found by titration.	Found by weighing barium carbonate.
.477 per cent.	.489 per cent.	.484 per cent.
.477 per cent.	.477 per cent.	.471 per cent.
.311 per cent.		
.312 per cent.	.325 per cent.	.310 per cent.
.314 per cent.		
.195 per cent.		
.196 per cent.	.205 per cent.	.193 per cent.
.194 per cent.		
.099 per cent.		
.097 per cent.		
.098 per cent.	.110 per cent.	.103 per cent.
.099 per cent.		
.102 per cent.		

It will be seen that in general the results are just a trifle low on carbon from other sources than steel, while the results on steel are distinctly higher by titration, and a trifle high by weight.

The cause of the errors in steel was traced to the formation of sulphurous and sulphuric acid from the carbonaceous residue. To obviate this error a solution of permanganate of potassium in sulphuric acid was interposed between the combustion tube and the barium hydrate. With this form of apparatus the following results were obtained, the combustion being made as before, but 30 minutes being used to aspirate :

Found by potassium hydrate.	Found by titration.	Found by weighing barium carbonate.
.603 per cent. .599 per cent. .594 per cent.	.60 per cent. .599 per cent.	.595 per cent. .594 per cent.
.477 per cent.	.473 per cent. .470 per cent.	.470 per cent. .465 per cent.

In order to test decisively this theory of the causes of errors four more determinations were made, using ten grams in each of a soft steel containing .075 per cent. carbon. Two of these combustions were made without interposing any permanganate. The results were :

Found by titration.	Found by weighing barium carbonate.
.084 per cent. carbon.	.080 per cent. carbon.
.084 per cent. carbon.	.079 per cent. carbon.

The precipitates of barium carbonate were now dissolved in hydrochloric acid and filtered. The barium sulphate found in first case weighed .0095 grams, and in second case .0075 grams. The results of the combustion corrected by these amounts give respectively .075 per cent. and .074 per cent.

The other combustions, interposing permanganate, gave the following results :

Found by titration.	Found by weighing barium carbonate.
.081 per cent. carbon.	.075 per cent. carbon.
.080 per cent. carbon.	.075 per cent. carbon.

The barium carbonate obtained from these combustions contained nothing insoluble in hydrochloric acid.

In conclusion I would say that it will be found much simpler to burn and weigh the barium carbonate rather than ot titrate. The high combining weight of barium renders it possible to weigh extremely small amounts of carbon when present as barium carbonate.

DISCUSSION.

The Chairman: The combustions made were those in our standard steels, the carbon contents of which we have a well defined knowledge.

The method of weighing the barium carbonate, which is much the more accurate, presents some striking advantages over the old method with potassium hydrate, among which is the saving of time in drying the residue, this is not at all necessary. Then the combustion proper can be hastened, as the flow of gas can be quicker without any danger from loss.

We have not found it at all necessary to interpose any drying tubes between the combustion tube and the absorption tube, nor was it necessary to take any further precautions against atmospheric carbonic acid in filtering than a moderate suction, which so hastens the operation that the error is nothing.

After further discussion the meeting adjourned at 9.30 P. M.

A. D. Wilkins,
Secretary C. S.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

APRIL 18, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Carnegie Library, Allegheny, Pa., on Thursday evening, April 18, 1895, Thomas H. Johnson, the President, in the chair. The meeting was called to order at 8:20, 35 members and visitors being present.

In his report for the Board of Direction the Secretary read the names of William E. Garrigues and George S. Bliss, the same having been passed upon by the board, to be voted on at the next meeting.

The names of Henry L. Barton, E. S. Johnson, E. E. Keller and Edward S. McClelland were then brought up for ballot, Messrs. Swensson and Davison being appointed as tellers. As a result of the ballot these applicants were declared duly elected.

The President reporting for the Committee on Quarters, stated that their efforts thus far were not successful. The house which they had hoped to secure on Penn avenue could only be obtained by renting from year to year; a time lease would not be given, and the rental asked was $900, which, taken in connection with the short term of the lease, the board felt that it could not take into consideration, and they are still searching for other quarters.

Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies, was present, and made an address in favor of the Engineers' Society of Western Pennsylvania joining the Association. After considerable discussion it was moved and seconded that the President be directed to appoint a committee of three members, charged with ascertaining all the facts in connection with the proposition of Mr.

Trautwine, and, after ascertaining these facts, condense them into a statement, to be mailed to each individual member for the purpose of deciding whether or not our Society shall join. Carried. The President appointed on this committee Messrs. G. S. Davison, Emil Swensson and H. J. Lewis.

Mr. E. D. Estrada then read a paper entitled "The Expansion of Cast Iron at the Moment of Solidification."

THE EXPANSION OF CAST IRON AT THE MOMENT OF SOLIDIFICATION.

BY E. D. ESTRADA.

The question as to whether cast iron expands or contracts in passing from the liquid to the solid state, is one which has been under discussion for a number of years.

In 1874, Robert Mallett communicated to the Royal Society the results of his experiments on this subject, and concluded that contraction, not expansion, as has been alleged, occurred during the change of state.

While it is not the purpose of the writer to enter into a minute discussion of the experiments of others, it will be proper to call attention to the uncertainties involved in Mr. Mallett's method, his object being to determine the specific gravity of liquid iron, and compare it with that of the same iron when solid ; to do which he proceeded as follows: After having determined the capacity of a circular vessel of wrought iron, it was filled with molten iron, additions being made from time to time as required by the expansion of the vessel. After being left to cool for three days, the wrought iron case was removed and the cast iron found to weigh 647.18 lbs. The capacity of the vessel when at its highest temperature was estimated to be 2,691.77 cubic inches, and since the molten iron supposed to have occupied this space weighed 647.18 pounds, the specific gravity of the molten iron was found to be 6.65. The specific gravity of samples taken from the casting was found to be 7.17.

A determination of the capacity of a vessel such as is used by Mr. Mallett at the temperature which he assumed (2,400° Fahr.) cannot be made with any degree of accuracy, because, while it may have been possible to determine the rate of increase in the capacity of the vessel within a very low and small range of temperature, it does not follow that the same rate would have applied to equal differences of temperature within the assumed range.

Supposing that the temperature of the liquid iron when poured in the vessel was in reality 2,400° (Fahr.) and that its volume was 2,691.77 cubic inches, due allowance should have been made for the contraction of the liquid before reaching the temperature of solidification.

It may be interesting to mention here the fact that, according to Daniel and others, cast iron solidifies at about 2,786° (Fahr). Further, if 7.17 represents the specific gravity of the samples taken from the casting after it had been cooling for three days, these figures could not represent the specific gravity of the same samples, if taken immediately after solidification, as in that event, the specific gravity should undoubtedly have been less, since the iron contracted in cooling, from the temperature of solidification to that of the atmosphere.

It is not in a spirit of ridicule that the writer criticises Mr. Mallett's methods, but because his conclusions were considered as proof positive that cast iron contracts in passing from the liquid to the solid state.

In 1879-80, Mr. Wrightson, in a paper read before the Iron and Steel Institute of Great Britain, proved conclusively to the satisfaction of such men as Dr. Siemens, Sir Lothian Bell, Mr. J. R. Stead and several others, that cast iron increased in volume in the passage from the liquid to the solid state. Mr. Wrightson evidently did not succeed in convincing everybody, since a few years after his paper was read, Mr. Charles Markham read a paper before the same institute, and his conclusions were directly opposed to those arrived at by

Dr. Wrightson. However, during the discussion which followed the reading of Mr. Markham's paper, it was clearly shown that Dr. Markham's methods were incorrect, inasmuch that, had the expansion occurred, the fact could not have been determined by his observations.

The description of several other experiments have come under the notice of the writer, but in every case either the difference in the physical condition of the iron when at the atmospheric temperature, and at the temperature of solidification has been entirely ignored; or the determination of the volume of a given quantity of iron, when liquid and when solid, has been inaccurately made. It matters not how small or how large the increase of volume is. The important point is to determine whether there is or not an increase; that done, there is an end to the question. What benefits may be derived by a knowledge of the fact, or to what practical use such knowledge may be put, is beyond the power of any one to predict.

In the experiments here described, it will be noticed that no attention has been paid to the per centage of increase in volume. The trials were made merely to ascertain the fact whether increase or decrease of volume takes place in the passage from the liquid to the solid state.

A wrough iron tube was placed in the center of a flask, and then surrounded by molten iron, as shown in the sketch marked I. When the tube became red-hot, it was filled flush with liquid iron from a hand-ladle. Immediately after the tube had been filled, the upper surface of the iron in the tube was chilled by means of some waste, previously soaked in cold water. Soon after this operation, molten metal began to ooze from the top of the tube, solidifying quite readily.

A similar tube heated to a temperature of about 150° (Fahr.) was placed near the flask and filled, within about one inch from the top, with liquid iron from the same ladle as the first one. Water was poured in the cavity at the top; the re-

sults obtained in this case were similar to those in the previous one, but not so marked.

The same trial was made by pouring liquid iron in a tube, previously heated to a light cherry red, and then allowing the tube and its contents to cool under atmospheric conditions. Two days after the experiments were made, the tubes were cut longitudinally, and it was found that the castings in the tube placed outside of the flask had large cavities near the center, and several small ones near the surface. The specimens are here for your inspection.

Notice that the casting in the tubes, which were hot before the iron was poured, do not exhibit any signs of shrinkage, while the casting in the cold tube does so. Notice, also, that the large cavities in one of the tubes are not due to the gases generated. A volume of gas with a pressure sufficiently high to raise the liquid above it, would not leave the surface of the cavities as they are found.

It is evident that the volume of iron in either tube was smaller while in the liquid than in the solid state. This being granted, we must admit that expansion takes place at the moment of solidification.

At the present time, the popular opinion among foundrymen, engineers, chemists, etc., is that a contraction takes place.

A writer on cast iron has lately expressed his opinion on the subject as follows: "The question has been raised whether cast iron expands at the instant of solidification. There is no such instant. Each crystal forms alone and shrinks on itself, and even if it did expand, it is not until such crystals are numerous enough to form a rigid shell that the casting can shrink, and any expansion of the crystal could not affect the whole casting. Cold cast iron floats upon fluid metal, because it has not become wetted by the fluid."

The fact is that the metal does not float until it has become wetted, for if a solid piece of cast iron is placed in a ladle containing liquid iron, it will sink and remain wholly immersed for some time, and then rise to the surface.

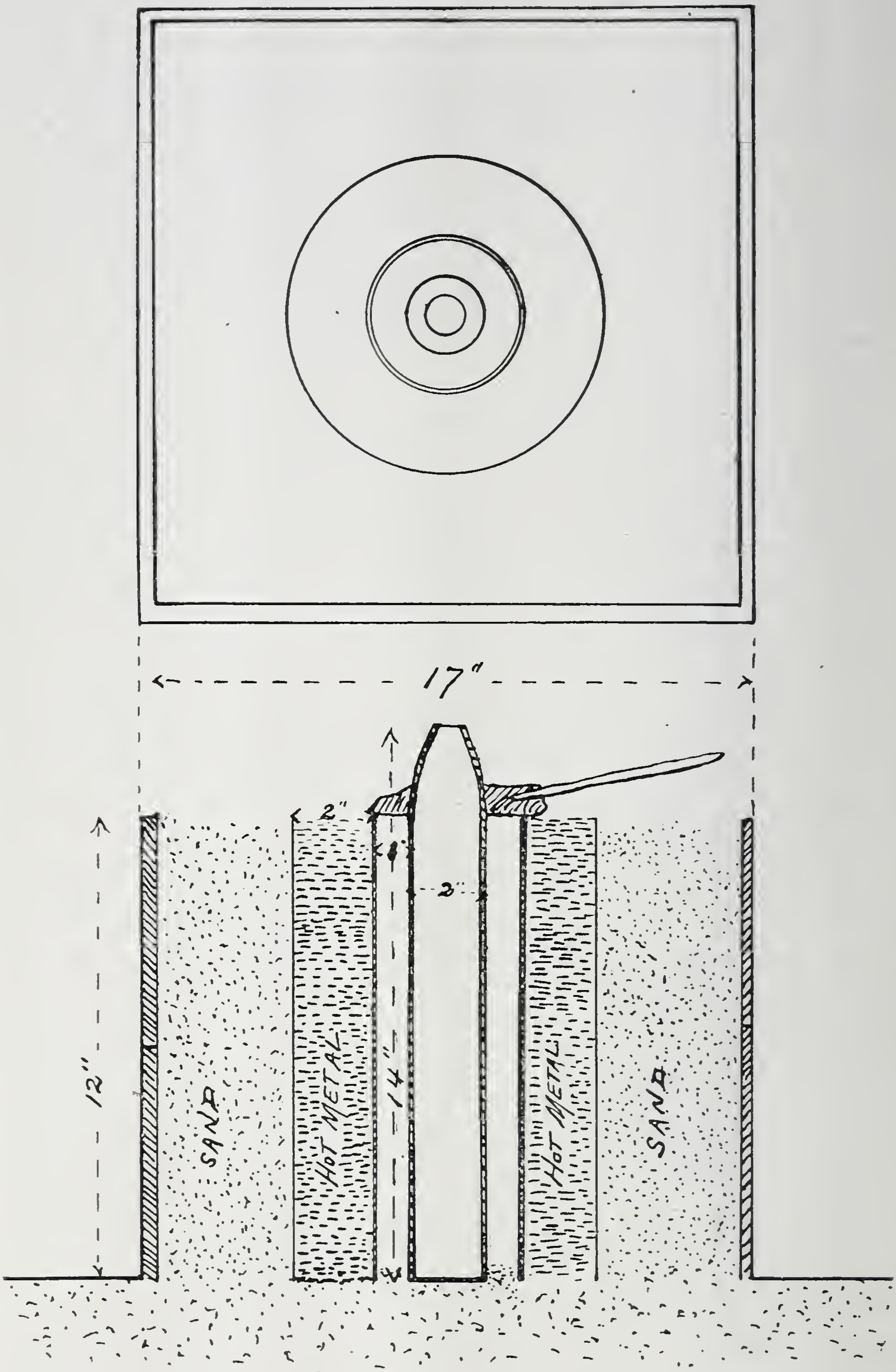


Fig. 1.

Mr. William A. Bole—Mr. Estrada seems to think that the general public takes it for granted that cast iron contracts in passing from the liquid to the solid state. That does not seem to be exactly the case. I find two places, one in the Encyclopedia Brittanica, and the other in Howe's Metallurgy, where it is recognized that iron, in passing from the liquid to the solid state, first expands, and then occurs the usual shrinkage which the gentleman spoke of.

From the "Encyclopedia Brittanica" the following, under the head of "Founding": "The metals best suited for foundry work are those that possess the property of increasing in volume at the moment of passage from the liquid to the solid state, so that its particles may be pressed into, and fill up the finest cavities of the mold in setting," etc., etc., and, in illustration, mentions cast iron among the metals having this characteristic.

From Howe's Metallurgy the following: "The floating of solid, on molten iron, is clearly due to the simplest of possible reasons, to wit, that the solid iron is lighter than the molten iron."

Some time ago I endeavored to account for some bad castings. I had found fault with the foundry-men because of some castings we had thrown away. They were filled with little fine shot, and my own opinion in this case was that, through carelessness on the part of the moulder, some metal had been splashed into the mould first and had scattered. That this metal ran across the surface of the mould, which was covered with graphite and soapstone, and each little globule became coated with an impervious skin of this material. When the metal followed in afterwards, the little shot floated on top. This theory called for the supposition that cold iron is lighter than molten iron, and, to test that matter, I had some experiments made in immersing cold iron in liquid iron. I think it can be clearly proven by most foundry-men that, when a piece of cold metal is thrown into molten metal, the cold portion will swim.

It is is not always safe to assume that, because you can throw a piece of cold iron into a molten bath, and find that it swims, that the specific gravity of the molten metal is greater, because that piece of cold iron might be porous, or hollow, but in all the trials I have made, cold iron will swim.

In Howe's experiments, he tested with balls. The difference between the specific gravity of cold and molten metal is very slight. The experimenter has to let go of the ball before it reaches the surface of the molten metal, and its own momentum carries it to the bottom, and, of course, it takes a little time for it to come up again, but experiments all show that it will rise.

THE PRESIDENT—Any further remarks?

Mr. A. Dempster here brought up the subject of the report of the Committee on Rooms, and, after considerable discussion regarding locations, the meeting adjourned.

DANIEL CARHART,
Secretary.

ALLEGHENY, PA., April 19, 1895.

MEETING OF THE CHEMICAL SECTION.

The regular meeting of the Chemical Section was held in the Lecture Room of the Carnegie Library, Allegheny, Pa., Friday evening, April 19, 1895.

The meeting was called to order at 8.10 by the Chairman, Mr. James M. Camp, fifteen members and three visitors being present.

The minutes of the last meeting were read and approved.

The Committee on Chemical Literature reported on the following papers:

"The Superiority of Barium Hydroxide Solution as an Absorbent in Carbon Determination in Steel," by Mr. James O. Handy, *Journal American Chemical Society*, April, 1895.

"Improved Methods of Water Analysis," by Mr. I. A. Bachman, *Journal American Chemical Society*, April, 1895.

"Some Properties of Calcium Carbide," by Mr. F. P. Venable and Mr. Thomas Clarke, *Journal American Chemical Society*, April, 1895.

"Volumetric Determination of Manganese," by Mr. Jos. Reddrop and Mr. Hugh Ramage, *Chemical News*, March 8, 1895.

Dr. K. F. Stahl reported the progress of the Directors of the Engineers' Society in their efforts to secure suitable rooms for the Society.

Mr. Robert Linton then read the following paper:

A STUDY OF GLASS AND THE RELATION OF ITS PROPERTIES TO ITS CHEMICAL COMPOSITION.

To chemistry is due much of the progress which has placed metallurgical operations where they now stand. The iron and steel industries have taken the lead in this direction, and in consequence of their excellent chemical control there is a precision in controlling the quality of steel that could never have been attained under purely empirical methods. What we know to-day of the chemistry of iron and steel is the result of years of study and work by many bright chemists and metallurgists, who have made a careful, systematic investigation of the various elements present as impurities in the metal, their effect upon the quality of the steel, and then as a practical application of it all, how the good are to be best utilized and the detrimental best removed. Going farther than the rational use of these impurities other elements have been added and new steels made which are the direct result of this chemical study of steel, and which the old empirical methods would never have stumbled upon.

What is true of iron and steel is true of all metallurgical operations. Those which are under the most intelligent con-

trol are bound to make the most rapid progress in their development. Theory and practice must be intelligently combined and controlled, and follow in general, speaking of chemical science, the method pursued by the steel chemists of studying the effect that the various elements we have in our special case, or that might be introduced, have upon the product we are making.

Now in glass making we have to do with a mixture of silicates, not less than two in number. When we consider the number of different silicates that may sometimes be formed on the same base, then when we think of the double silicates and the possibility or rather probability of their formation in a complex mass such as glass, it is not surprising that out of the accumulation of analyses of glass that have been made, no definite structure expressed by a chemical formula has been established. All we say is, that it is a mixture of various simple and compound silicates, mutually dissolved in each other. Yet if we examine and compare the analyses of the best grades of glass we will find a certain similarity in structure worth noting. If we make a melt of a mixture of silica, a fusible base and an infusible base, it is evident that the fusible base will tend to form a more acid silica than the less fusible. If we melt sand, soda and lime together, the silicate of soda will tend to have more silica than the silicate of lime. As the latter is very refractory, we may not unreasonably assume that the silicate of soda formed is the same that is formed when soda is melted in excess of sand or silica, or Na_2O4SiO_2. This, then, may act as a solvent for the other base or bases, and the remaining silica which unite and remain as silicates in solution. In the case of lead flint, we have again a second easily fusible base which probably may form an acid silicate like the alkali. Let us now see how formulas for different kinds of glass worked out on this assumption compare with the composition as determined by analysis. In the case of alkali-lime glass we have :

$$\begin{array}{r} Na_2O4SiO_2 \\ CaO\ SiO_2 \\ \hline Na_2OCaO5SiO_2 \end{array}$$

Analysis of good brands of window and plate glass will usually show a composition varying from $O.6Na_2OCaO4SiO_2$ to $Na_2OCaO5.5SiO_2$. In the case of lead flint we have a mixture of two easily fusible silicates, and consequently in melting, the tendency to form acid silicates of both bases and give the glass a high percentage of silica. Assuming that the soda and lead, melting at about the same temperature, form silicates of similar structure, then we would have for crystal, which contains a great deal of lead, the following structure :

$$\begin{array}{r} Na_2O4SiO_2 \\ 2PbO8SiO_2 \\ \hline Na_2O2PbO12SiO_2 \end{array}$$

The average of the analyses of three of the best brands of crystal on the market give the formula :

$$Na_2O2PbO11SiO_2$$

Taking finally the example of a mixed lime and lead flint, and assuming the formation of silicates as in the preceding cases, we will have the structure :

$$\begin{array}{r} Na_2O4SiO_2 \\ PbO4SiO_2 \\ CaO\ SiO_2 \\ \hline Na_2OPbOCaO9SiO_2 \end{array}$$

I have never analyzed a glass of this kind, but an analysis by Tscheuschner gives the following formula :

$$1.3K_2OPbO0.8CaO9SiO_2$$

Of course we cannot say with certainty that the silicates in glass have this structure, for we cannot separate them. But it is interesting to notice the number of cases to which this assumption will apply.

In this connection a word about devitrification, or the condition of glass in which it loses its transparency owing to the formation of minute crystals in the glass, or more rarely of large, well defined crystals in a bed of transparent glass. This crystalline glass shows in general more lime and less alkali, and the clear glass surrounding it shows excess of alkali. Accordingly it has been suggested that the crystals are crystals of silicate of lime separated out of the solution of silicate of alkali. This view is, however, scarcely reasonable, and the crystalline part is probably no less glass than the transparent part, formed when the glass remains long enough in the molten state to allow the molecules to search each other out and arrange themselves in an orderly and regular shape. But as the glass in which the crystals are imbedded, and out of which they have separated, is rich in alkali, here again, as in melting, the silicate of alkali seems to act as the solvent for the others.

Weber has established as a formula for the normal glass, or that which may be taken as a standard in point of resistance to decomposition or any chemical change under the influence of the atmosphere, acids, etc., the following:

$$R'OR''O6SiO_2$$

in which R'O is an alkali and R''O an alkaline earth or metal. The group of elements that may come under the second head is a large one. Including the metallic oxides used to color glass, not less than 19 belong here. Other salts than silicates are also often found in combination with them, comprising phosphates, borates, fluorides, arseniates, antimonates, stannates. Making a classification of all the elements that we meet in glass making, we may form three general groups as follows :

1. Alkalies.
   - Sodium.
   - Potassium.
   - Lithium.
2. Other bases.
   - *a.* In colorless glass.
     - Calcium.
     - Lead.
     - Aluminium.
     - Barium.
     - Magnesium.
     - Strontium.
     - Thallium.
     - Zinc.
   - *b.* In colored glass.
     - Cadmium.
     - Chromium.
     - Iron.
     - Gold.
     - Cobalt.
     - Copper.
     - Manganese.
     - Nickel.
     - Selenium.
     - Silver.
     - Uranium.
     - Antimony, and antimonates.
     - Tin, and stanniates.
3. Acids giving the following salts:
   - *a.* In transparentglass.
     - Silicates.
     - Phosphates.
     - Borates.
     - Fluorides.
     - Arseniates.

b. In opaque glass.
Phosphates.
Stannates.
Fluorides.

Having thus classified the elements, let us now make a general classification of the various kinds of glass so as to show the relation between their properties and the different elements that enter into their composition.

1. Alkali-lime glass.
2. Alkali-lead glass.
3. Opaque glass.
4. Colored glass.
5. The recent chemical and optical glass.

Silicate of soda, soluble glass, is a transparent, colorless, amorphous substance, that has not been obtained in a crystalline form. Acids decompose it, forming silicic acid and a salt of soda corresponding to the acid that has effected the decomposition. It melts at a comparatively low temperature, and has the power of dissolving a certain amount of silica. Though the commercial article has a generally uniform composition, there are several silicates of soda, any of which might be formed in a glass melt. The corresponding silicates of potash have properties similar to those of the silicates of soda. Since these are so easily decomposed, and since they dissolve silica and other silicates and oxides so readily, the hardness, durability and other properties of glass are dependent upon the quantity and nature of the other silicates held in the silicate solvent, or as it is technically called, flux. In the case of alkali-lime glass the dissolved silicate is silicate of calcium. The silicates of calcium are among the most refractory of the silicates, and in making the glass hard and durable it makes it at the same time more refractory. Expressed according to Weber's formula this glass should have the formula $Na_2OCaO6SiO_2$. In reality few of all the different forms of

alkali-lime glass will be found to correspond with it very closely, though the best grades of window, plate and bottle glass agree in the particular that the bases are present in about equal molecular proportions, and these varieties may be taken as the ones that have to endure the most severe practical tests. The following are analyses of various types:

	I.	II.	III.	IV.	V.	VI.
SiO_2 —	69.48	70.71	69.82	71.47	74.07	72.62
$Al_2O_3Fe_2O_3$ —	2.59	1.92	2.58	1.21	1.20	1.80
CaO —	13.40	13.38	7.82	9.39	8.25	8.22
MgO —	0.26	——	——	0.20	0.09	——
Na_2O —	14.55	13.25	18.28	16.69	8.63	5.19
K_2O —	——	——	1.50	——	7.47	11.81

I.—$Na_2OCaO5SiO_2$	Belgian window glass.
II.—$Na_2OCaO5SiO_2$	French plate glass.
III.—$Na_2O.5CaO3.5SiO_2$	German bottle glass.
IV.—$Na_2O.6CaO4.4SiO_2$	German mirror glass (blown.)
V.—$Na_2O.7CaO5.6SiO_2$	Bohemian chemical glass.
VI.—$Na_2O.8CaO6SiO_2$	Pressed glass.

Now, in practise, it is found that in making a durable glass the lime and flux should be present in the mix in proportions which will be such as to make the quantity of each, molecule for molecule, equal. That is, in a mix where 32 lbs. of lime is used to 100 lbs. of sand, the equivalent of sulphate of soda would be about 45 lbs. In this country the proportion of sulphate is not as high, for it is high-priced, and so our furnaces are fired to melt a batch a little more refractory than this. However, if the lime be increased beyond a certain limit the glass will become stony and rough, as the silicate of lime is so refractory. On the other hand, if too little be present, the glass will have a tendency to be cordy, coarse, and less durable. Such glass is frequently met with in green bottles, especially of foreign make. Of the other elements present in small quantities, magnesia makes the glass harder and more brilliant, but more infusible ; alumina makes the glass more

fusible and easier to work, but ought not to be present in quantity above 5 per cent., as it increases the tendency to devitrification. Taking, again, alkali-lead flint, we have a glass in which in place of lime, or along with it, we find oxide of lead. Silicate of lead is among the most fusible of the silicates, as silicate of lime is among the most infusible. We find correspondingly a difference in the properties of the glass, which is used for entirely different purposes from the lime glass. The lead flint is distinguished by its fusibility, brilliancy, refractive power, softness, and high specific gravity. Its use is therefore mainly confined to ornaments and optics. Three analyses of glass made by Weber are as follows:

		I.	II.	III.
SiO_2	—	53.70	53.70	52.41
$Al_2o_3Fe_2O_3$	—	1.12	1.07	0.96
CaO	—	0.17	0.59	0.77
PbO	—	37.02	34.91	35.24
K_2O	—	7.36	9.12	10.37
Na_2O	—	0.70	0.30	—
MgO	—	—	—	0.08

I.—$K_2O2PbO11SiO_2$ Val St. Louis.
II.—$K_2O16PbO9.2Sio_2$ Val St. Lambert.
III.—$K_2O1.4PbO8SiO_2$ Baccarat.

However, lead may be present in much higher quantities. One specimen I analyzed had the following composition :

Sio_2	—	38.35
$Al_2O_3Fe_2O_3$	—	0.52
CaO	—	0.70
PbO	—	53.52
K_2O	—	3.63
Na_2O	—	3.67.
As_2O_5	—	0.27

Oxide of lead was doubtless dissolved in the glass, as a very distinct yellow tint also goes to show. Another peculiar feature of this glass is the large percentage of arsenic remaining in the glass. I will refer to this again later on. Lead

flint often contains, in addition to the regular components, baryta, lime, borax, zinc, or magnesia. Its peculiar properties are, however, due to the influence of the lead, and they are more marked, as the percentage of lead rises. The object of the others is to give a harder, or more durable, glass. Baryta is very commonly used for this, and in alkali-lime glass as well. Barium is the element of the group of alkaline earths which most closely resembles the alkalies. In using it in glass-making it replaces the lime or lead of the typical varieties, and, as it partakes of the properties of the alkalies on the one hand, and the alkaline earths on the other, we find that glass melted with baryta melts and clears up easier than a soda-lime glass, and when used with lead in lead-flint, it makes it only a little less fusible and brilliant, and decidedly more durable. There is a tendency to cordy glass sometimes, as when too much flux is used. Some manufacturers in this vicinity have been using it with lime in soda-lime glass recently, and have in some cases reported favorably, in others adversely, with regard to it. European manufacturers have had it in use for both lime and lead glass for some years.

Colored glass is merely one of already noted types of glass having in solution a small amount of a metal metallic oxide or silicate which colors it the desired tint. The following are the principal elements used in this :

Red :—Gold, copper, selenium.

Green :—Copper, chronium, iron-FeO.

Yellow :—Cadium, sodium, sulphide, silver, uranium, iron-Fe_2O_3.

Blue :—Cobalt, copper.

Violet :—Manganese.

One of the most interesting studies to the chemists, however, is the process of decolorization, which is the neutralizing or removing any tint that interferes with making a colorless, transparent glass. The one great difficulty that we have to encounter in this is the almost universal presence of iron in our

raw materials. Reference to the above list shows that ferrous oxide colors glass green and ferric oxide yellow, but there is a great difference in the intensity of the coloring effect of the two. A quantity of iron which, when present as ferric oxide, imparts a color scarcely perceptible to the glass will, if present as ferrous oxide, impart a very noticeably and often unpleasant green color. Since the iron cannot be gotten rid of entirely, we naturally should try to get rid of as much of it as possible in form of ferric oxide. This is done by adding to the glass certain decolorizing substances, notably arsenic, manganese, nitre, and oxide of nickel, which react as follows:

$$2FeO + 2KNO_3 = Fe_2O_3 + K_2O + 2NO_2$$
$$6FeO + As_2O_3 = Fe_2O_3 + As_2$$
$$2FeO + MnO_2 = Fe_2O_3 + MnO$$
$$2FeO + Ni_2O_3 = Fe_2O_3 + 2NiO$$

The nitrous fumes, and also usually the arsenic pass off and assist the melt by stirring up the glass. Manganese silicate is a violet color, and a little of it serves to further neutralize the iron color, according to the physical law of complementary colors. We should note, however, that in making glass the iron is never entirely oxidized to ferric oxide. The temperature of the furnace is too high. Bontemps made a series of experiments on the color of various mixtures of ferrous and ferric silicates, and arrived at the conclusions shown by the following table:

$6FeO1Fe_2O_3$	—	Black.
$3FeO2Fe_2O_3$	—	Blue.
$2FeO2Fe_2O_3$	—	Green.
$2FeO3Fe_2O_3$	—	Yellow.
$1FeO3Fe_2O_3$	—	Orange.
Fe_2O_3	—	Red.

A practical demonstration of the same thing is that glass made in a tank furnace has a more bluish-green color than glass made in a pot furnace. The latter melts a batch containing a chemical decolorizing agent, the former a batch without it.

An equally interesting study is furnished by opaque glass. As referred to above, if glass stands too long in the molten or semi-molten state, it will become opaque, owing to the formation of fine crystals. The commercial opaque glass owes its opacity to another cause. Some white, amorphous substance is, in this case, held in solution or separates out as a precipitate, and is held suspended as such in the glass, and this is either a fluoride or phosphate, or in the case of enamels may be a stannate, an antimonate, or oxide. Much nonsense has been written on the cause of opacity in glass made with creolite, or of a mixture of fluor spar and feldspar. It has been assigned to fluoride of sodium, fluoride of aluminum, undecomposed creolite, NaFSiF, and even to simple devitrification, the latter view having been held by no less a distinguished authority than Benrath. Fluoride of aluminium seems, however, to be the substance in question. Two analyses I made gave the following results :

	I.	II.
SiO_2 —	59.85	71.53
$Al_2O_3Fe_2O_3$ —	10.71	4.85
ZnO —	8.13	——
CaO —	——	4.81
Na_2O —	14.07	2.18
K_2O —	——	14.86
F —	6.18	1.77
As_2O_3 —	0.91	——

These and other analyses I might refer to show considerable alumina and fluorine, and enough alumina to unite with all the fluorine present. Of two experimental melts I made, one with fluor spar alone, and the other with fluor spar and feldspar, the former gave a clear glass, the latter an opaque glass. Both fluor spar and feldspar are used to some extent in the manufacture of green bottles. If a melt of opaque glass be allowed to stand too long, it will become clear, showing a decomposition of the fluoride and the escape of the fluorine as tetrafluoride of silicon. In the case of opacity produced by

using phosphate of lime, this compound is probably held in suspense as a precipitate. Opaque enamels, made by the use of oxide of tin or antimony, contain probably stannate or antimoniate of soda, or it is possible that the oxides remain intact.

In addition to these salts, which may be dissolved in glass, ordinary glass may also contain borates—principally alkaline borates, in all probability. Their presence make the glass more fusible and adds to its brilliancy and refractive power. I might add that the borate glass often has a light bluish tinge where much boric acid is present. A small quantity of arsenic is also sometimes retained. I found in two cases 0.27 and 0.91 per cent. respectively. The complete analyses have been already given. It is usually claimed that arsenic is never present in more than the most minute quantities, and I have never found more than a trace in alkali-lime glass. Probably the presence of the metallic silicates tends to retain the arsenic in the glass and contributes more to this than the fusibility of the glass analyzed. The glass in which I found 0.91 per cent. was a piece of old "Hot Cast Porcelain," made a number of years ago when this ware began to be popular. I am told that the batch of that time contained an excessive amount of arsenic, as it was thought that this helped to make a quick and easy melt. This glass contained no lead, but on the other hand quite a good deal of zinc.

Glass-making is not without its curiosities, and among them we may find glass which contains no silica, but is merely a mixture of phosphates or of borates and phosphates. It is a clear glass, but will stand no exposure. Another curiosity is glass without alkali, where the latter is replaced by baryta and the mixture helped along by the addition of boric acid. Such examples are to be regarded as abnormities, and not only cannot be classed as glass from a chemist's standpoint, but they do not have the physical properties of glass, except its transparency and amorphous form.

As we come to better understand the metallurgy of glass, and become more familiar with the various elements entering into its composition, we may hope to utilize them better, and be able to produce with more exactness a uniform grade of glass, with a constantly rising standard of quality.

DISCUSSION.

Mr. Robert Linton—Has anyone present ever found arsenic in glass in quantities such as my two analyses gave?

Prof. F. C. Phillips—I think it is quite common to find arsenic in Pittsburg window glass. I have found it in a number of samples—about half a per cent.

Mr. Linton—It is generally used in the mixture more or less, but it is claimed that it volatilizes and passes off.

Prof. Phillips—Yes; the glass manufacturers themselves often think so.

The Chairman—Arsenic occurs in steel, found originally in the ores. If it can stand the ordeal of the blast furnace temperature and then the still higher one of conversion into steel, it is reasonable to suppose it would be found in the glass after the melt.

Prof. Phillips—Referring to the glass having the analysis:

Silica	69.48
Iron and alumina	2.59
Lime	13.40
Magnesia	.26
Soda	14.55

Was that a durable glass?

Mr. Linton—Yes; it was a very durable glass. The best plate and window glass generally shows a composition varying not a great deal from that.

Prof. Phillips—Is there any satisfactory explanation of the fact that window glass and plate glass, having the same composition, will differ as regards the action of the weather—that the one may fade, and that the other does not? The fading

seems to be the great difficulty with Pittsburg manufacturers. They do not seem to have been able to account for it yet.

Mr. Linton—As yet that has not been satisfactorily accounted for. Window glass from one factory often fades more than that from another, although the mixtures may be very similar.

Prof. Phillips—It has been supposed that it is due to the action of wet straw when it is packed; but even when packed only for a short time, or put at once into windows, it will often fade. It is a very common thing to see whole rows of windows in houses where every pane of glass shows the rainbow colors, and yet plate glass never seems to show it at all. The plate glass with the grinding it gets ought to have a more open surface than window glass that has been fused and flattened, and ought really to have more tendency to fade than window glass, but it is not the case.

The Chairman—Do you mean that it is iridescent—that it looks like a sheet of water with oil on it?

Prof. Phillips—The colors take all sorts of curves in irregular directions. Here in Pittsburg, it is a common thing to dip the glass in hydrochloric acid. They even began dipping it in two per cent. hydrofluoric. Such treatment has been found to prevent fading, but cannot always be depended on.

Mr. Linton—They do that in Belgium, too.

Prof. Phillips—Do they use hydrochloric acid?

Mr. Linton—Yes, and sometimes they use sulphuric acid. They say that it is simply to clean the glass.

Prof. Phillips—Is there any explanation of the red color due to gold in glass? Why is it that the gold does not show the red color until heated intensely?

Mr. Linton—There are several theories in regard to the color produced by gold. The most satisfactory is that it is a very fine separation of metallic gold, like the case of opaque glass, when calcium phosphate is the agent which produces the

opacity. It is supposed that the calcium phosphate separates out, and is held as a sort of a precipitate in solution. The same explanation has been offered with regard to the gold—that the gold as a metal separates out under heat, and is, as it were, held in suspension, and I believe this theory is quite generally accepted now.

Prof. Phillips—It is in combination with the glass when the glass is first made?

Mr. Linton—That is according to the theory that has been advanced.

Prof. Phillips—Are the large tank furnaces being used abroad as they are here?

Mr. Linton—Yes. The tendency is not towards such very large tanks as has been the tendency in this country. I think the largest tank furnace in Belgium is a 48-blower, 16-ring tank. A number of them are from 24 to 36-blower tanks; but in Belgium there is no plain window glass at all made in pot furnaces. It is all made in tanks.

Mr. W. E. Garrigues—Isn't it thoroughly established that some of the arsenic does volatilize in the melting?

Mr. Linton—Oh, yes.

Mr. Garrigues—That most of it does, I mean.

Mr. Linton—I think it depends a great deal on the nature of the glass. In window glass, I was always under the impression that the greater part of it volatilizes, and only a trace of it left.

Mr. Garrigues—I heard that discussed not long ago. That is the reason I asked. I heard people discussing it who held different views. I do not know anything about it myself. I would naturally suppose most of it would volatilize.

Mr. S. G. Stafford—For what sort of articles is that lead glass used? Is it only a curiosity? I never saw any glass so high in lead.

Mr. Linton—I do not know where this glass came from, but judge it to be an experimental glass made for optical pur-

poses; experimenting to find the limit to which lead could be used to advantage. Artificial gems have a similar composition.

THE CHAIRMAN—The analysis given of the chemical Bohemian glass is the composition of the standard glass which is used pretty nearly exclusively for chemical ware in this country, is it not?

MR. LINTON—Yes; I believe it is.

THE CHAIRMAN—American glass will often break stored in the cupboard.

DR. K. F. STAHL—I had some flasks made of American glass that were claimed by the manufacturer to be as good as Bohemian. If one was put on a hot place quickly, it would crack. The whole thing does not break; you can usually save the analysis. I noticed on some which broke, that they were too thick at the bottom. The trouble seems to be due more to the making than to the quality of the glass.

MR. GARRIGUES—Suppose you wanted to imitate Bohemian glass, and make a mixture having the actual composition of Bohemian glass, can it be made?

MR. LINTON—There is a difficulty in taking an analysis of glass, making up a mix, and putting it into a furnace and melting it. A mix that succeeds in one furnace may not succeed in another. The furnaces may not both melt in exactly the same way.

MR. STAFFORD—Suppose you used carbonate of potash and carbonate of soda with silica in each instance, do you not think the results would be the same?

MR. LINTON—They might and they might not. It is very difficult to get two furnaces to act in exactly the same way, and materials from different sources often act diffe ently.

MR. STAFFORD—Of course, in the manufacture of plate glass where you use sulphate of soda, there might be some difficulty about the decomposing of the salt cake, I can understand that.

MR. LINTON—Where a mix for glass has been made up

from analysis, and has been tried in other furnaces, sometimes it has succeeded and sometimes failed. Just as in the case of making chemical glass in this country. In general, we have not been able make so good a grade of chemical glass as the Bohemian.

THE CHAIRMAN—The workmen play a very important part in the production of good glass.

MR. GARRIGUES—I have heard the superiority of Bohemian glass ascribed to the source of the silica it is made from, which is obtained in Bohemia or in the neighborhood. I do not know whether there is anything in it or not.

MR. LINTON.—The nature of the materials certainly has a great deal to do with the quality of the glass.

MR. GARRIGUES—There are certainly many people who have tried to make that glass.

MR. LINTON—And generally with very little success.

MR. GARRIGUES—There is quite a difference in laboratory glass. Some of the flasks used are of more refractory glass than the combustion tube.

MR. LINTON—The combustion tubes are made of a slightly different composition, I believe, and there is also some variation in the composition of glass made in different Bohemian factories.

MR. GARRIGUES—The combustion tube has peculiar fine lines on it.

MR. LINTON—That is probably due to some defect in melting or working the glass.

MR. GARRIGUES—I have often noticed it. There are hair lines about an inch long running through it ; they look like a fine grain in wood.

MR. LINTON—That is merely a little defect which becomes elongated in drawing the tube out. The tube is first made by a workman blowing out a little ball of glass; a second workman fastens an iron rod to the bottom of this ball, and then the two workmen gradually walk away from each other,

and draw the tube out between them. Any small defect, such as seeds or blisters or striae in the glass, would be drawn out, and that probably gives the appearance you refer to.

PROF. PHILLIPS—I had a very good German tube which was exposed to a heat of 500° for some time, and I found the tube completely warped out of shape, so that it was actually twisted. It actually seemed that the long-continued gentle heat produced the same effect as a stronger heat. I never knew that was true of glass before.

MR. LINTON—Did you ever notice, too, the glass devitrifying in your combustion tube?

PROF. PHILLIPS—Yes; I have noticed that. It seems to me glass must have a very uncertain fusing point in that case.

MR. LINTON—A good many hold to the view that glass is merely a stiffened liquid, something like sealing wax.

Adjourned.

A. D. WILKINS,
Secretary C. S.

PLATE I.

Engineers' Society of Western Pennsylvania.

May 16, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Art room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, May 16, 1895. The meeting was called to order at 8.20, Thos. H. Johnson, the President, in the chair, and 20 members and visitors present.

The minutes of the last meeting were read and approved.

The names of G. S. Bliss and W. E. Garrigues having been brought up for ballot, the President appointed as tellers Messrs. Lewis and Schellenberg. All the votes cast were in favor of the applicants, and they were therefore declared duly elected.

Mr. G. S. Davison then read the following memorial on the death of W. C. Quincy, formerly a member of the Society :

Walter C. Quincy was born at Baltimore, Md., January 16, 1831, and departed this life February 3, 1895, respected and revered by all with whom a long and useful life had thrown him in contact. He was educated in the schools of his native city, and was reared by a mother whose sterling and Christian character added in every way to develop in the boy noble virtues and rare intelligence, that was constantly demonstrated in manhood.

At the age of eighteen years he entered the service of the Baltimore & Ohio Railroad Company, and remained with that company for twenty-nine years, holding positions of honor and trust from the beginning.

His services during the Rebellion, while engaged as engineer of the main line and branches of the Baltimore & Ohio Railroad, and charged with the transfer of troops and military supplies for the United States Government, deserved special

commendation, and he received the highest endorsement from the Secretary of War and Manager of Military Railroads for his executive acts and loyal devotion to his duties and country. Though born in a State and under circumstances which would naturally enlist his sympathies for the Southern cause, yet never for a moment did he swerve from his loyalty and devotion to the Union.

Mr. Quincy was elected General Manager of the Pittsburg & Lake Erie Railroad Company, October, 1878; President of the Pittsburg, McKeesport & Youghiogheny Railroad, August, 1881, and continued to hold these offices until January, 1888, when he was made General Manager of the Monongahela Connecting Railroad, which position he held until his death.

In the service of the Pittsburg & Lake Erie Railroad Company his previous varied experience in the department of railway work enabled that company to develop and maintain one of the most valuable railway systems in America. His knowledge as an engineer gave him great advantage over the ordinary railway men.

He had few peers as a railway manager, and as an engineer possessed those qualities and conservative skill which gave him high rank in the profession.

Careful and considerate in his official life, with an honest purpose as an arbitrator between the vast interests represented by him and the public, as well as employe, won for him the reputation of a just and good man.

That he was public spirited and patriotic to the interests of this community is evidenced by the active part he took in all movements for public welfare.

His last work in life was to act as Chairman of the Committee on Invitation and Reception of the 28th National Encampment of the Grand Army of the Republic, and as such he mapped out the programme of that most important committee just as his health was rapidly failing him.

His heart was always tender in an appeal for mercy, quick to forgive a trespass, yet firm in the discharge of a duty when discipline demanded it.

By his death his wife was bereft of a kind and loving companion ; the city of a useful citizen, whose counsel was frequently sought, and this Society an honored and much-respected member.

George S. Davison,
Rawdon Evans,
Charles Davis,
Committee.

It was voted that the report be received and spread upon the minutes.

Mr. G. S. Davison, on behalf of the committee appointed at the last meeting to consider the question of this Society joining the Association of Engineering Societies, stated that the committee had reviewed the subject carefully, as per instructions, condensed the facts into a report, which was printed and mailed to each member of the Society prior to this meeting, which is as follows :

REPORT OF COMMITTEE ON ASSOCIATION OF ENGINEERING SOCIETIES.

The undersigned committee, appointed at the last meeting of the Society, to investigate and report by letter to the members, upon the feasibility of this Society becoming a member of the Association of Engineering Societies, would respectfully report the following :

The object of the Association of Engineering Societies is "to secure a joint publication of the papers and transactions of the participating societies." By such a plan it is designed to place in the hands of each member of the said societies, the papers of all these societies, and at a small cost. The following Engineers' Clubs or Societies are members : Boston, Chi-

cago, Cleveland, St. Louis, St. Paul, Minneapolis, Kansas City, Montana, Virginia and Denver. Also the Technical Society of the Pacific Coast. The total membership is about 1,350. The annual subscription price to the Journal, of which there are ten numbers per year issued, is three dollars. Each Society is expected to subscribe for a copy for each of its members, and any financial gain or loss to the Association is shared according to the number of copies the Societies order. During the fourteen years of the Association's existence, the cost of publication of the Journal has never been less than three dollars per copy per individual member.

Should our Society join the Association it would add about 450 to the individual membership, and would constitute one-fourth of the Association. It would be represented on the Board of Managers by 5 out of 23 members that would constitute the Board, the largest single representation. Chicago and Boston have three each.

The accession of our Society would add strength to the Association in membership, and increase the number of papers to be published. As we would most likely furnish our proportion of matter to be printed, there would be no financial gain to the Association, except that the general expenses (an item of about $1,000 per annum) would be paid by 1,800 individuals, instead of 1,350, as at present.

The Journal of the Association is conducted in a most admirable manner, and our transactions and proceedings would undoubtedly be published therein with as much consideration as in our own Journal.

The question of whether this Society should become a member of the Association or not, should be settled upon the side of the predominating advantages, both as they affect our Society and also its individual members.

The advantages of joining would be that each member would receive in one publication the papers of a number of Societies, and that this Society and also the authors of its

papers would be more widely advertised than could be expected through our own Journal. The first advantage is not so great as it may seem, as the Journal of the Association can be had by any person, at the subscription price. The latter advantage affects the authors of papers more than the Society, and the question of just how far the Society should go in advertising its members, when it costs money to do so, should be carefully considered. Any paper may make a reputation for itself and author, in proportion to its merit, and there is not a single case of a paper of unusual merit that has been prepared for our Society, that it has not been widely noticed and published in the prominent journals of the times, and the author at least, and usually the Society, has been given credit for the same.

The disadvantage of the union can be summed up as a financial one.

To publish our own Journal at present, the net cost to the Society is about one dollar per year per member. The Journal of the Association would cost the Society about three dollars per member, or probably an additional sum of $800 above the present cost. The increase could not be met by the Society without increasing the dues of the members sufficient to make up the entire amount.

Although the dues of the Society are as low as any, and lower than most of the other local Engineering Societies, this Committee does not think it advisable, at this time, to impose any further tax upon the members of the Society, for this purpose, as any of our members may secure the Journal of the Association by private subscription.

This Society has been, and may again be, criticised for not embracing what may seem to be a splendid opportunity, and incidentally aiding the Association in its good work. To such criticism we would answer that this Society has always been alive to its interests, and no better proof of it is needed

than its large membership. In the meantime it is ever ready to make a reasonable sacrifice for the general welfare of the engineering profession and its societies.

The question will be submitted to a vote at the regular meeting on May 16th. If you find you cannot be at the meeting, please communicate your views to us, and they will be given to the Society during the discussion of the question.

Respectfully,

GEO. S. DAVISON,
EMIL SWENSSON,
HARRY J. LEWIS,
Committee.

Upon motion of Mr. Schellenberg, and properly seconded, it was voted that the report of the committee be accepted, laid on the table, and the committee discharged.

The question of taking an excursion on the river was then discussed at some length, after which it was moved and seconded that the Reception Committee consider the advisability of the Society having an excursion, procure data in regard to the same, and give their decision at the next meeting. Carried.

THE PRESIDENT—On behalf of the Board in the matter of rooms it would be proper for the Chair to report that about two weeks ago, in response to a request of Mr. Macbeth on behalf of the Trustees of the new Carnegie Library, a meeting was held at the new building, at which I think all the members of the Board, the Committee on Rooms, and one or two other members of the Society, were present. At that meeting a document was read, which had been prepared by the Trustees, assigning quarters to the Academy of Science and Art and allied societies, on condition that the societies using these quarters pay the salary of the curator, which, it was supposed, would be about $2,500 to $3,000 a year.

Under the arrangements which have heretofore existed be-

tween the Engineers' Society and the Academy of Science and Art, the proposition of the Trustees would require the Engineers' Society to pay somewhere in the neighborhood of $1,200 per year as rental, and the members of the Board have not seen their way clear to report to the Society anything looking toward favorable action. We do not see how, in our present financial condition, we can afford to pay that amount of rent; but I understand from Mr. Scaife that the Trustees have a modified proposition by which the allied societies might accept, and I would like to hear from him.

Mr. Scaife, Mr. Wilkins and others here discussed to some length the matter of accepting the quarters offered, but no further action was taken.

Mr. W. G. Wilkins then read a paper entitled "The Reconstruction of the Sixth Street Bridge."

THE RECONSTRUCTION OF THE SIXTH STREET BRIDGE AT PITTSBURG, PA.

BY W. G. WILKINS.

The Sixth Street Bridge at Pittsburg, Pa., is a good example of the evolution that has taken place in highway bridge building in this country during the present century.

In 1810 some of the more progressive inhabitants made up their minds that a better means of communication was needed between the boroughs of Pittsburg and Allegheny than the ferry-boats which had served the purpose up to that time. The result was the first bridge, which, with its well-built masonry and wooden spans of one hundred and eighty-five feet, must have been considered a very creditable piece of engineering for those days.

Time passed on, the wooden bridge began to decay and a new bridge became necessary. Col Jno. A. Roebling was called upon to design the new structure, and the more modern wire suspension bridge, with its spans nearly double that of the old, was decided on and built.

The travel continued to increase, street car tracks were laid over the bridge ; in 1890 heavy electric cars came into use on the lines crossing the bridge, and it was found too narrow and light for the heavy traffic. The company decided that it had outlived its days of usefulness, and must make way before the march of progress. The decision was that a new bridge was imperative, which decision resulted in the new steel truss bridge which forms the principal subject of this paper.

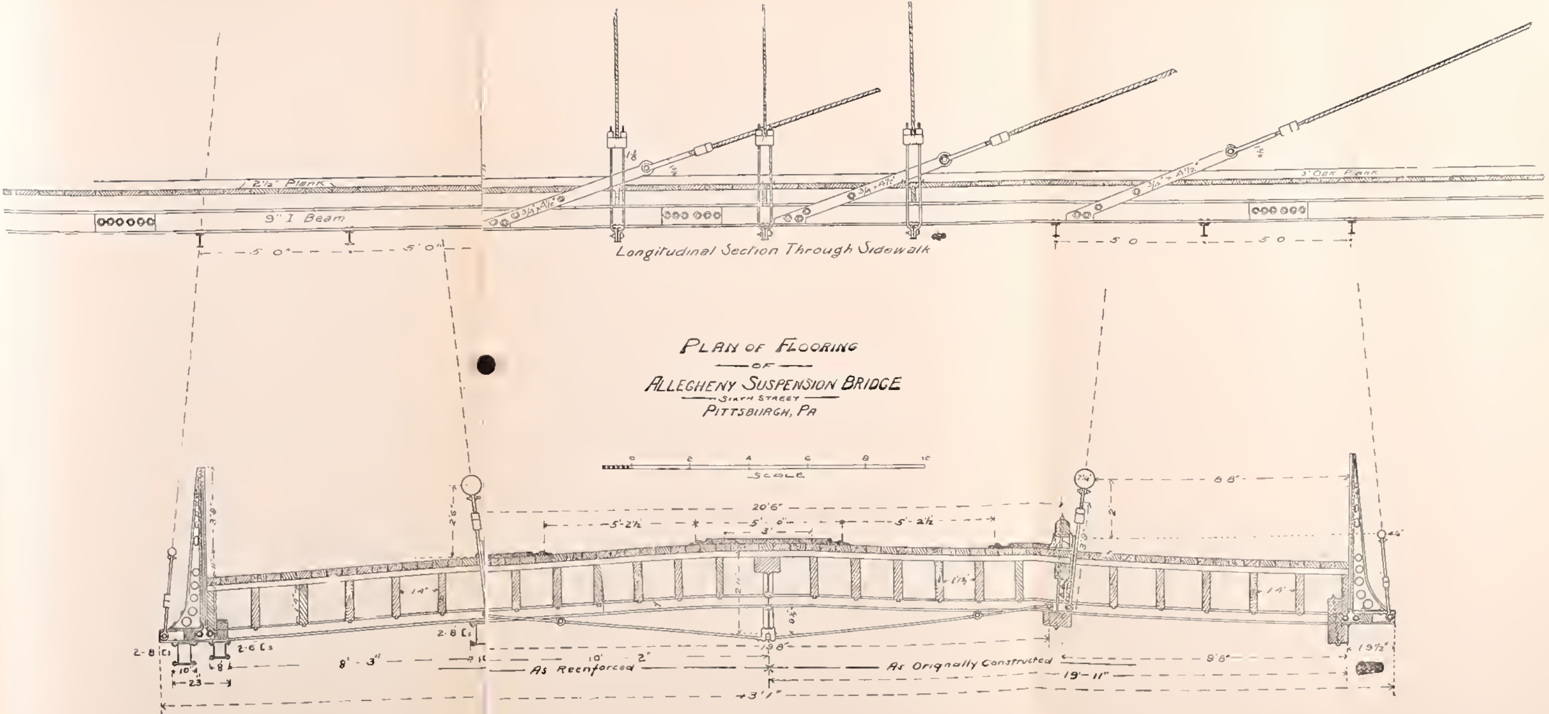
The Sixth Street Bridge is the main thoroughfare between the business portions of the cities of Pittsburg and Allegheny. It spans the Allegheny river, connecting Sixth street in the former city with Federal street in the latter, and for many years was the only highway bridge connecting the two cities. The company owning the bridge was chartered in 1810, and its corporate title is, "A company for erecting a bridge over the Allegheny river opposite Pittsburg in the county of Allegheny."

The first bridge was built in 1819 by Mr. Lothrop, a prominent contractor of that time, who also built the Ninth, or Hand Street Bridge, as it was formerly called. This latter was torn down about four years ago and replaced by a steel bridge suitable for rapid transit, the work being done under the direction of Messrs. Ferris and Kaufman, members of this society.

The first bridge consisted of four spans of 185 feet each, one 170 feet, and one 137 feet ; total, 1,037 feet. The superstructure was of wood, and the trusses were probably of the Burr type, as in the Hand Street Bridge, reinforced with wooden arches, as the skew backs can still be seen in the Allegheny abutment.

The roof was flat, and had a railing at the sides and steps at each end. It was used as a promenade by the belles and beaux of days gone by.

The old wooden structure stood for forty years, when it was torn down to be replaced by the wire suspension bridge.



2½" Plank
9" I Beam
3" Oak Plank
Longitudinal Section Through Sidewalk
Plan of Flooring
of
Allegheny Suspension Bridge
Sixth Street
Pittsburgh, Pa
Scale
As Reenforced
As Orignally Constructed

PLATE 2.

While the latter was being built there was no attempt made to take care of the traffic, and the old bridge was entirely removed before the work was begun on the new one.

The Suspension Bridge.

The Allegheny Suspension Bridge was long noted as the most beautiful and graceful in its lines of the earlier bridges built by the late Jno. A. Roebling, and a brief description may not prove uninteresting before passing to the subject proper of this paper. A photographic view is shown on Plate 1, and a cross section on Plate 2.

There were two main spans of 344 feet each, and two shore or half spans of 177 feet and 171 feet. The main cables at each side of the roadway were 22 feet apart c. to c., at the center of the spans, and 27 feet at the towers. The smaller cables at the outside of the sidewalks were 42 feet apart at center of spans and 35 feet at the towers.

The main cables were $7\frac{1}{2}$ inches in diameter and composed of seven strands of 700 wires each, and weighed 115 pounds per foot. The smaller cables were $4\frac{1}{2}$ inches in diameter with 300 wires, and weighed 38 pounds per foot. These weights include the wrapping wire, and are actual weights obtained by weighing sections of the cables after they were taken down.

The cables passed over saddles supported by towers, each formed of four cast iron columns 22 inches in diameter and about 27 feet high.

The floor beams were 7-inch I beams 43 feet 1 inch long, and were spaced 5 feet c. to c. They were suspended from the cables by wire ropes 1 inch in diameter, which were attached to the cables by wrought iron collars. The lower end of these wire ropes were attached to the stirrup which supported the floor beams. Near the centers of the spans, where the suspenders were short, they were of $1\frac{1}{4}$-inch rods instead of wire rope.

These floor beams were curved to give the proper crown to the roadway.

On top of these floor beams, at the center and ten feet each side were lines of 9-inch I beams running the entire length of the bridge, which were riveted to the floor beams.

On the center line, and under the floor beams and riveted to them was another line of 8-inch I beams. Between the upper and lower I beams there were fillers of cast-iron, I beam shape extending from floor beam to floor beam. The two I beams and the filler were riveted together. The lower beams acted as a strut for the truss rods which trussed the floor beams the width of the roadway. On the under side of the floor beams, at 10 feet and 19 feet 6 inches each side of the center line, there were 10x10-inch timbers running the full length of each span. These timbers were replaced by box girders, as shown on Plate 2, when the repairs were made after the fire in 1881.

The floor joists were 4x18 inches white pine. The joints of the joists were halved for three feet and bolted together, making the joists practically continuous. The joists were fastened to the floor beams by "U" bolts.

The floor consisted of a course of $2\frac{1}{2}$-inch white pine plank laid transversely, and on this a 3-inch course of white oak laid longitudinally.

Beginning at the second floor beam from the piers, and then at every second beam to the twenty-first, there were, in addition to the vertical suspenders, wire rope stays, which ran from the longitudinal I beams up over the saddles and down to the corresponding beam on the other side of the pier. Where these stays crossed the suspenders they were lashed together with small wire. Plate 2 shows a cross section of the floor.

On Sunday, June 19th, 1881, the floor of the bridge was discovered to be on fire, and it was four hours before it was entirely extinguished. Wagon travel had to be discontinued for several days while repairs were being made. In making the repairs it was decided to strengthen the bridge somewhat,

and the longitudinal 10x10 inch timbers were replaced by box girders, on the two main spans. These girders abutted on the masonry of the piers, and when taking down the bridge these girders were found to be buckled fully eight inches out of line in the panels immediately adjoining the middle pier. During warm weather these girders probably acted as arches, and relieved the strain on the cables to a certain extent.

In 1883, Mr. Francis Collingwood, Member of the American Society of Civil Engineers, repaired the cables at the anchorages, splicing 175 wires in one cable and 107 in the other. He also had all the old paint scraped off the cables and repainted. A full account of the work done under his direction is given in the Proceedings of the Institute of Civil Engineers for 1883-4, Part 2, Page 334.

In 1888 Mr. W. Hildenbrand was employed to make an examination of the cables and anchorages. He cleaned the anchor bars from tar and rust, and coated them with linseed oil and red lead, two coats, and imbedded them in paraffine mixed with beeswax and rosin. He also treated the wires where they joined the links in the same manner. He also saturated the cables with oil, the oil being poured in at many places along the cables. Four and one-half barrels of oil were thus used. When the cables were taken down this oil was found to be still moist.

He reported to the company on completion of his work "that the wire is in as good condition as new, that the anchorages are so thoroughly protected that they are good for at least 100 years, and that the wires, where they passed around the shoes, will need no examination for the next 20 or 25 years." The writer can say, from his examination of the work when the bridge was torn down, that he fully agrees with Mr. Hildenbrand's conclusion, and that the only necessity for replacing it was that it was too light and narrow for the heavy traffic it was called on to take care of.

In taking down the bridge, crystallization was found very

marked in the rods forming the stirrups supporting the floor beams. It seldom required more than one blow with a sledge on the nut to break these rods. Nearly every one broke close to the nut, and the fracture showed the crystallization very strongly. In some cases the nuts themselves would break in two, and the fracture showed crystallization as marked as in No. 1 Bessemer Pig.

Most of the floor beams, and, in fact, all the iron that was exposed to the action of the gases in the smoke from the steamboats passing under the bridge, showed quite a large reduction in cross section.

On cutting the cables at the center of the spans the wires on the outside showed slight oxidization, but the rest were in as good condition as the day they were put in place. Over the saddles the wires were not in strands, but in one large bunch. The lower wires, or those in contact with the saddles, were all very much flattened, and some of them so badly rusted that one or two bends by hand would break them.

The writer, through the courtesy of the Pittsburg Testing Laboratory, is enabled to give the following results of tests made by them, showing relative strength of splices and wire :

Numb'r of Tests.	Diam't'r Before Tests.	Diam't'r After Tests.	Maxim'm Load Lbs.	Tensile Strength Lbs. per Sq. in.	Red ct'on of area, Per cent.	Remarks.
5,514	....	....	1,350	....	....	Splice from over saddle.
5,515	....	....	1,200	....	....	" " " "
5,516	....	....	1,200	....	....	" center of span.
5,517	....	....	1,175	....	....	" " " "
5,518	....	....	1,250	....	....	" " " "
5,519	.145	123	1,400	84,800	28.04	Wire from over saddle.
5,520	.143	125	1,320	82,800	23.60	" " " "
5,521	.143	135	1,200	74,720	10.90	" " " "
5,522	.143	119	1,350	84,060	30.76	" " " "
5,523	.143	130	1,350	84,060	17.37	" " " "
....	.144	....	1,450	89,015	51.00	Wire test by Collingwood, 1883.
....	....	....	1,350	....	....	Splice test by Collingwood, 1883.

The splices did not break by the wires pulling apart, but one of the wires always broke opposite the end of the other

wire, and in one of the nicks where it was wrapped with the small wire. Disregarding test No. 5,521, which was made on a piece of wire very badly rusted, it will be seen that the splice showing the poorest result had an ultimate strength of 90 per cent. of the wire showing the lowest result. The highest result of splices was 96 per cent. of the highest result of wire. The tests made by Mr. Collingwood in 1883, when he repaired the bridge, showed the splices to have a strength of 93 per cent. of the wire.

The total amount of metal in the bridge, by actual weighing after it was torn down, was:

Cable	150 tons
Cast iron	325 "
Wrought iron	350 "
Small wire rope	50 "
Total	875

The bridge had stood for 32 years, eight less than the wooden structure, when the company realized that in these days of rapid transit it was inadequate for the traffic, and determined to replace it by a more durable and commodious structure.

The New Bridge.

In 1891 Mr. Theo. Cooper, Member of the American Society of Civil Engineers, was appointed engineer for the company, and instructed to prepare plans and specifications for a new bridge capable of taking care of the rapidly increasing travel, and which would allow the electric cars to cross without moderating their speed. The plans, as prepared by him, provided for a masonry approach on the Pittsburg end 105 feet long, with two arches each 28 feet span, two main spans of 445 feet, and a girder deck span 48.5 feet.

The plans required the erection of two piers, one near the middle of the river, and one on the Allegheny shore, and the cutting down and altering the Allegheny abutment, so as to make it conform to the new work. Before the contracts were

awarded the writer and Mr. Geo. S. Davison, members of the Engineers' Society of Western Pennsylvania, were appointed Resident Engineers.

The plans were approved by the Secretary of War, and the contract for the masonry was awarded to The Drake & Stratton Company, Limited. Mr. J. Wainwright, Member of the Engineers' Society of Western Pennsylvania, is the Vice President of that company, and he gave his personal attention to the supervision of the work for the contractors. A detailed account of this portion of the work is given further on.

The specifications prepared by Mr. Cooper for the superstructure provided generally as follows:

Superstructure to consist of two spans, each about 440 feet, and one deck span about 36 feet in clear. Clearance between end posts to be 41 feet 6 inches. Footwalks 9 feet wide outside of trusses. Spans to be so designed as to conform to general plans and profiles approved by Secretary of War. Roadway and footwalks to have buckle plate floor. Bridge to have two street car tracks, 9 feet c. to c., with provisions for putting in a cable conduit at any time in the future. Clear head room to be at least 18 feet.

Floor and its supports to carry live load of 100 pounds per square foot, or 30 tons on two pairs of wheels 10 feet apart. Main trusses to be proportioned for a moving load of 80 pounds per square foot of floor surface, and 40 pounds per square foot of sidewalk, and 130 pounds per square foot of the roadway. Lateral and sway bracing to be proportioned for 250 pounds per lineal foot of span. Range of temperature of 75 degrees, Fahrenheit, above and below mean, to be provided for.

Maximum strains not to exceed those allowed by Cooper's Highway Bridge Specifications, 1890.

Buckle plates to be 5-16 inch thick, crowned 2 inches, pitch of rivets not more than 4 inches. Sidewalk buckle plates to be inverted.

Provisions to be made for gas and water pipes, and suitable expansion plates to be provided.

Competitors to submit with their designs strain sheets, giving separately strains from live and dead loads.

Bids to cover taking down of the Suspension Bridge.

The proposal and design submitted by the Union Bridge Company, Chas McDonald, Member of the American Society of Civil Engineers, President, was accepted as the best, and the contract awarded to that company.

The design accepted was of the bowstring type, 439 feet 3 inches c. to c. end pins and 79 feet high at center, and trusses 44 feet 6 inches apart c. to c. The general features of the main spans and appearance of completed structure are shown on Plate 3.

The laying out of the lines for the new bridge was an easy matter, no triangulation being necessary.

The work was all done between four and six o'clock in the morning before much travel had begun.

The center line was measured on the floor of the old bridge, and tacks driven at the centers of each of the piers. The transit was set over each point and right angles turned off and referenced by driving plugs in the ground far enough away from the bridge so as not to be disturbed during construction.

The river or No. 2 pier was referenced on the Seventh and Union Bridges, and also on a platform built on the breakwater piling. The last point was used as a transit point for centering the new pier.

All the measurements were made with a 100-foot Chesterman steel tape, and checked by a different set of men from the ones who made the first measurements.

In the erection of the new bridge the center line at the Pittsburg end was shifted down stream about six feet, so as to bring the center line of bridge on the center line of Sixth street at Duquesne way. The cables and towers of the old

bridge had to be removed, and the floor of the old bridge had to be elevated enough to permit the erection of the new bridge floor underneath it.

The car tracks had to be shifted from one side of the bridge to the other three times to allow stringers and buckle plates to be put in place. This had to be accomplished without the interruption of traffic, and was safely done as to foot and street car traffic, and could have been completed without stopping vehicle traffic. The directors of the bridge company were fearful that some accident might possibly happen if horses were allowed to cross, and, feeling that the amount of toll they would lose would be less than the amount of damages they might have to pay in case of an accident, they decided, as noted further on, to suspend vehicle traffic.

A description of the methods used in construction of masonry and erection of the superstructure is the province of this paper, rather than a theoretical discussion of the design of the superstructure.

In building the foundations no attempt was made to go to rock, either by excavation or driving piles. Rock under both the Monongahela and Allegheny rivers in the neighborhood of Pittsburg is about sixty feet below the bottom of the rivers. None of the bridges in the city limits have the bottom of their foundations lower than seemed necessary, at the time they were built, to get below the limits of scour. In the neighborhood of some of them the narrowing of the channels by dumping slag along the banks has increased the current, and consequently the scouring of the bottom so much that the river piers are in danger of being undermined, and in order to prevent this large quantities of heavy rip-rap stone have been dumped around them.

The only bridge in the vicinity that has foundations reaching to rock is the Ohio Connecting railroad bridge over the Ohio river, at the lower end of Allegheny City, where pneumatic caissons were used.

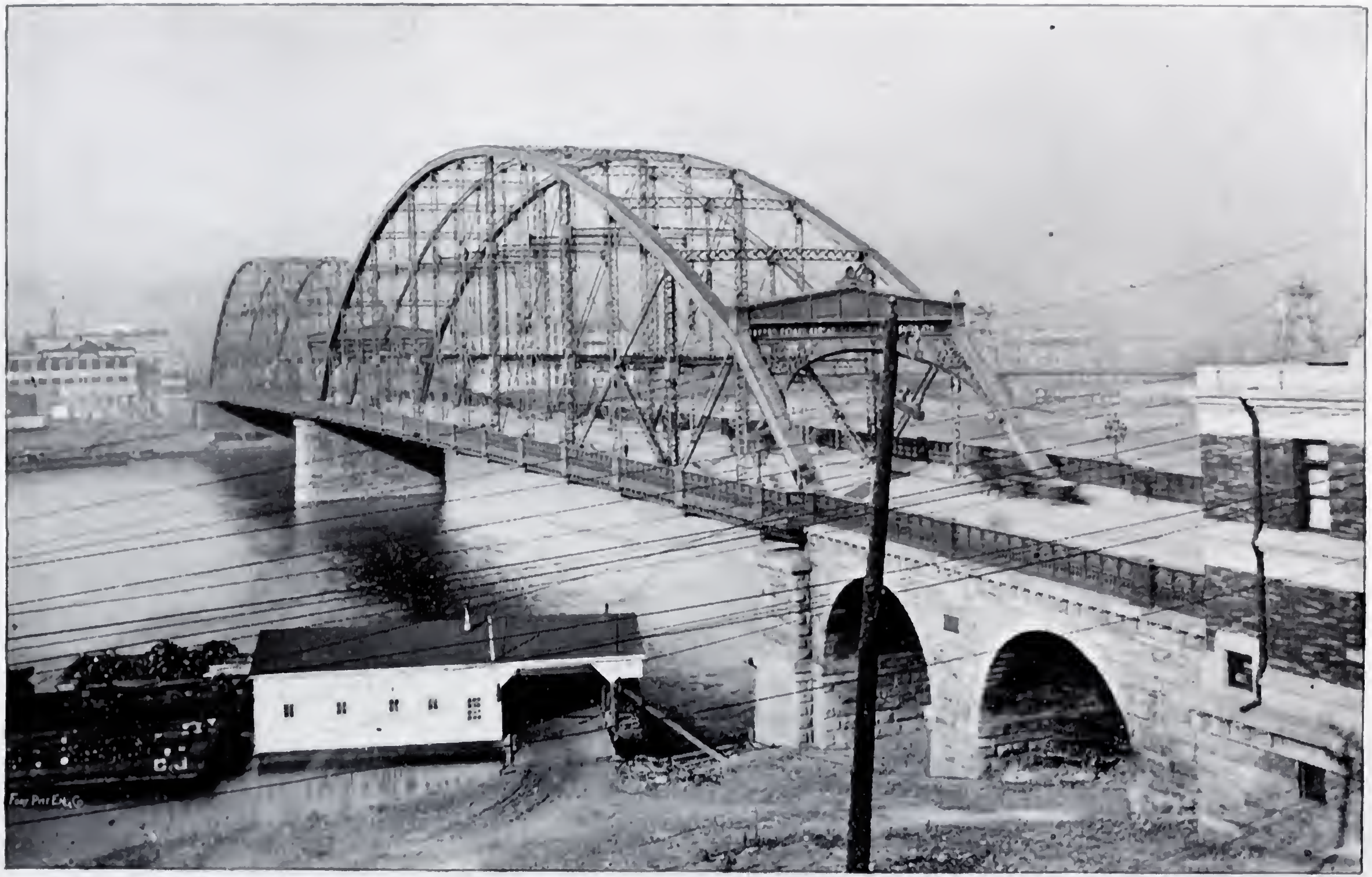
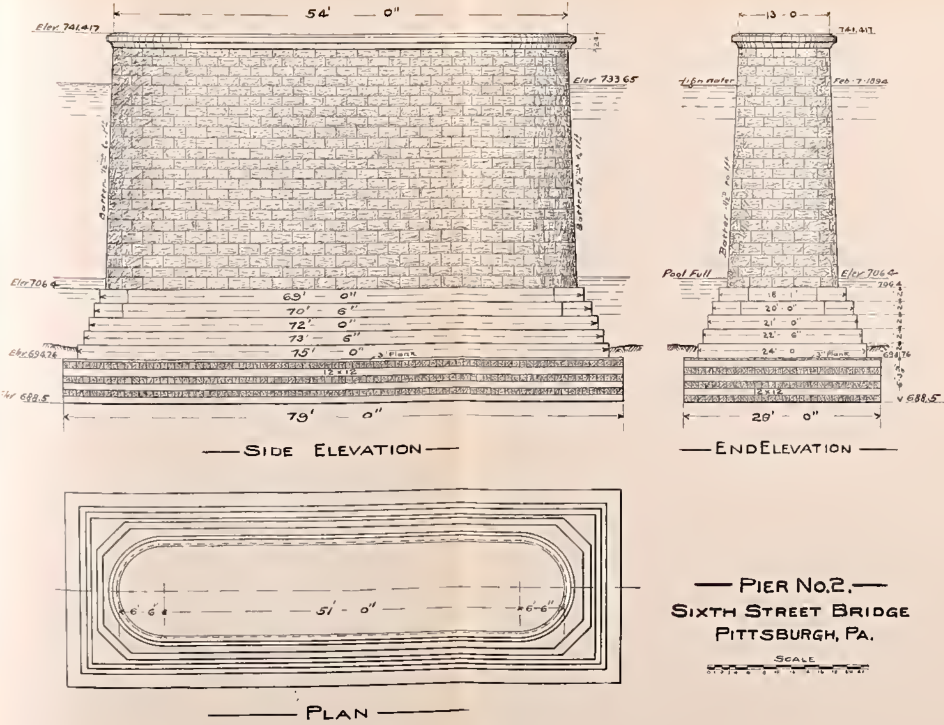


PLATE 3.


54' 0"
Elev. 741.417
Elev. 733.65
High water
Feb. 7. 1894
13 - 0
Pool Full
Elev. 706.4
69' 0"
70' 6"
72' 0"
73' 6"
75' 0"
3" Plank
12 x 12
Elev. 694.76
Elev. 688.5
79' 0"
16 - 1"
20' 0"
21' 0"
22' 6"
24' 0
28' 0"
Side Elevation
End Elevation
6' 6"
51' 0"
Plan
Pier No. 2.
Sixth Street Bridge
Pittsburgh, Pa.
Scale
Plate 4.

In the Sixth Street Bridge, while the old piers had stood for years, with the bottom of the foundations so shallow that at low water the top of the timber footings were exposed, it was deemed advisable to get the foundations for the No. 2 pier deeper than the old work, and deep enough to prevent any possibility of danger from scour. The river bottom is good, solid gravel for many feet in depth, and the bearing power is sufficient to sustain the weight on the piers without piling. For this reason it was decided to simply dredge out the bottom and use an open coffer-dam, built on the timber grillage which forms the footing courses of the pier.

For the Pittsburg shore piers and abutment it was decided not to be necessary to go any deeper than the gravel for a foundation, as there could be no possibiblity of the scour reaching that deep.

Masonry.—The masonry of the piers consists of rock-ranged work with rubble backing. All corners have quoins 2x3 feet. All the masonry, except coping and cornice of approach, is Beaver county (Pa.) sandstone, and the coping and cornice are of Berea (O.) stone.

The cement used was Louisville, "Black Diamond" brand, and was tested with a Fairbanks machine, and gave results of from 60 to 100 pounds in twenty-four hour tests of neat cement.

Pier No. 2 (see Plate 4).—This pier, which is in the middle of the channel, was the only part of the masonry that had anything especially interesting connected with it. The new pier was within 10.5 feet of the old pier, and the bottom of the foundation was 7.6 feet lower than that of the old pier. Great care had to be taken to protect the old pier, as it had to support the old bridge until the false works could support the old floor.

The Allegheny river is subject at certain seasons to very sudden rises and a very swift current. In order to protect both the old and new piers during the construction of the lat-

ter, a breakwater was constructed about 80 feet upstream from the new pier, so as to deflect the current away from the work. Plate 5 shows the general arrangement of this breakwater. It consisted of piles driven so that their tops stood about 25 feet above low water. String pieces of 6x12 white oak were bolted to the piles, and outside of them was driven white oak sheet piling as close together as it could be driven on the two sides forming the apex of the triangle, the whole well braced crosswise. The south wing was extended down stream past the nose of the old pier. The piles of this work also served a very good purpose for attaching the ropes, which controlled the position of the coffer-dam while sinking.

Alongside of the old pier next to the new one were driven piles as close together and as close to the old masonry as possible. These piles were anchored back to the old pier by rods foxed into the masonry. String pieces were bolted to the top, and sheet piling back of them was driven till the lower end was below the bottom of the new pier.

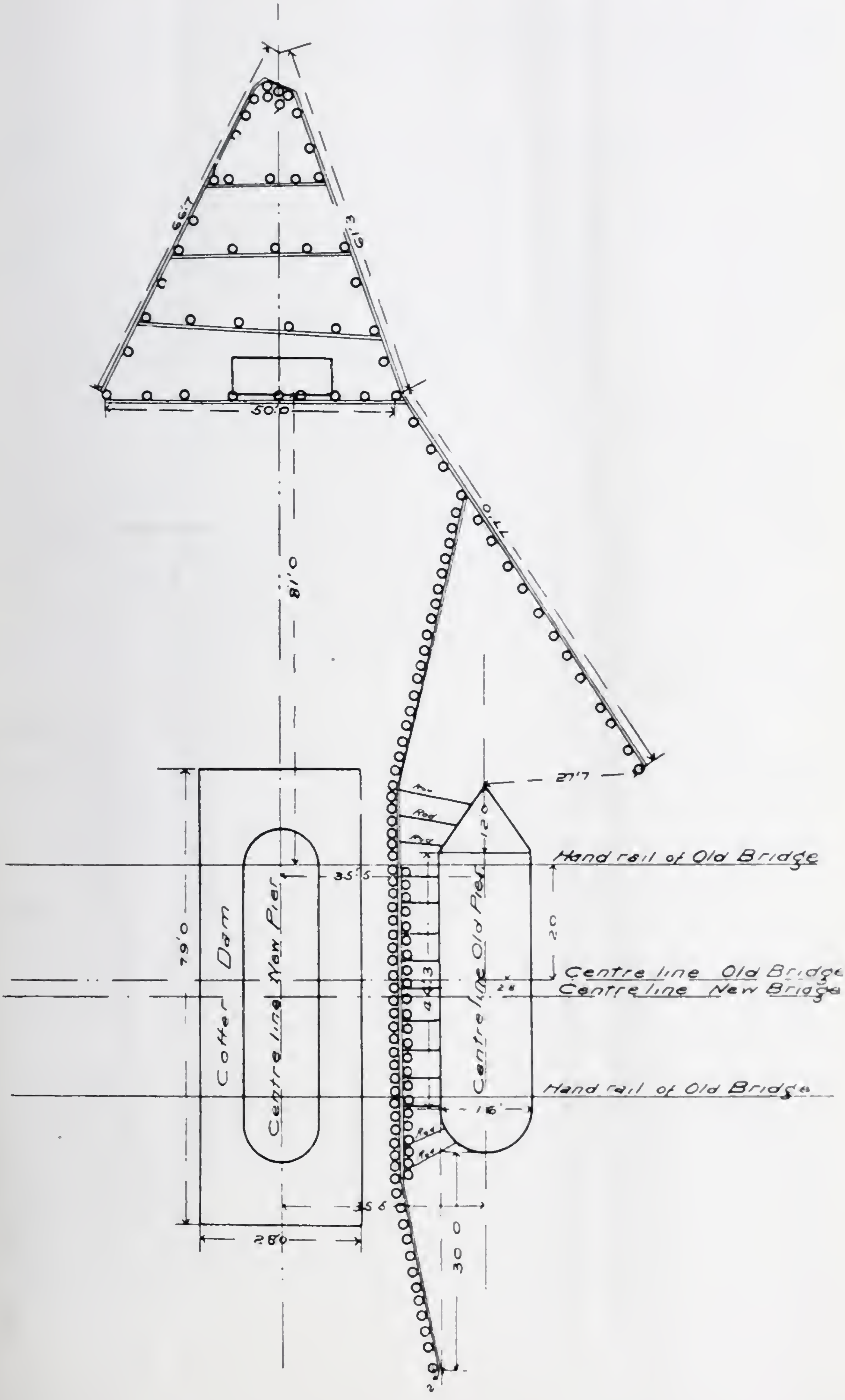
When this protection was completed the dredging for the coffer-dam was proceeded with. The construction of the coffer-dam was also begun, so as to have it ready to sink when the dredging was completed.

The bottom of the coffer-dam was built at the shore and towed out to below the breakwater, where the sides were put on. The bottom which formed the footings was composed of six courses of 12x12-inch timber drift bolted together.

Pockets were left on each course, except the bottom, which were filled with enough gravel to sink it so that the top of deck was level with the water when completed.

On top of the upper course of 12-inch timber was spiked a deck of 3-inch oak plank, the joints being filled with white lead and caulked with oakum. Around the edges of this deck was vertical studding 4x6 inches, 16 feet long, 24 inches c. to c., and mortised into the deck.

On the inside of the studding were two lines of string


66.7
61.3
50.0
81.0
77.0
27.7
12.0
Hand rail of Old Bridge
35.5
20
Cotter Dam
Centre line New Pier
Centre line Old Pier
Centre line Old Bridge
Centre line New Bridge
79.0
44.3
2.8
Hand rail of Old Bridge
16
35.6
28.0
30.0

pieces of 6x8 inches, one line being 4 feet from the bottom and the upper 12 feet from the bottom, or 4 feet from top of studding.

Every 6 feet between the string pieces on opposite side were 8x8-inch struts. There were also diagonal braces of the same size from the center of each end string piece, running at an angle of 45 degrees to the side string pieces. In addition there were two struts running along the center line from end to end. The siding was 2-inch hemlock plank, the edges being beveled, making the joints a little wider on the outside.

The joints are thoroughly caulked from the outside with oakum, making the dam water tight. The entire amount of lumber in the dam above the deck was 15,000 feet, board measure. It was not thought necessary to make the dam more than 16 feet deep, for the probability of having a stage of water that would go over the dam was small; even if it did happen, it was only a question of a few hours' pumping to empty it. This did not occur until the masonry was above the top of the dam.

When the masonry reached the lower sets of struts, they were taken out one at a time, and the sides of the dam braced at that point by blocking between them and the masonry, and the same done when masonrywas up to the second set of struts.

After the dredging had been nearly completed a diver was sent down to examine the foundation of the old pier, and it was discovered that the sand and gravel was caving out from under it. Additional sheet piling was driven, and the space between piling and masonry filled with broken stone and gravel, and the dredging proceeded. The piling of breakwater and dredging were started July 6th, 1891, and on September 10th the coffer dam was dropped down to place. On the 13th the masonry was started, and on the 15th the coffer dam had settled to the bottom. The pier was completed on November 9th, with the exception of a small part under the floor of the old bridge, which could not be done till the floor was removed.

While building the masonry the coffer dam kept settling, and not always evenly. After each course of stone was laid, levels were taken, and the next course was made thicker at the proper end to level up. By the time the pier was half up settlement ceased, and the last course was cut down in place to the correct elevation to receive the coping.

The excavations for the foundations for the other piers and Pittsburg abutment (see Plate 6) were in open cut, and the sides supported by sheet piling. The footings consisted of four courses of 12x12-inch timbers drift bolted together. In excavating for Pier No. 3, three courses of timber were taken out that had formed the footings of one of the piers of the original wooden bridge, and which were put in place in 1819. The timbers, when first taken out, appeared as solid as when first cut, but, on drying out, showed every appearance of dry rot. In building the abutment only one-half was excavated at a time, and the masonry well up before the excavation for the other half was begun, as it was not thought advisable to excavate the full width of the old abutment to the bottom of it while it was still taking the strain from the cables of the suspension bridge.

After the new bridge was completed, the old piers were torn down, and the bottom of the river dredged out, so as to leave nothing to interfere with navigation.

The piers torn down were of about the same quality of work on the face as the new, but the backing consisted of very much smaller stone.

The faces were held together by long rods of iron, with the ends turned down and doweled into the tops of the face stone on each side. There were about a half a dozen of these rods in each course.

When tearing down the channel pier on the Allegheny side, it was discovered to be one of the original piers widened out three feet. The old pier was on timber footings, and the new part rested on two rows of piles, cut off below low water level. The new stone work was anchored back to the old by foxed

bolts. During the thirty years the pier had carried the Suspension Bridge, there was no sign of craking between the old and the new work.

ARCHES.—The arches that formed the Pittsburg approach were built up under the floor of the old bridge.

Centers were provided for one-half of the length of the arches, and, in laying the arch stones, the inner end was toothed so as to make a bond with the other half. After the first half was keyed up to the centers, and lagging was dropped down on gas pipe rollers, and the whole rolled over on the false work and blocked up to receive the rest of the arch.

The backing of the arches was heavy rubble and concrete. The table on page 164 shows the quantities in foundation work.

ERECTION OF SUPERSTRUCTURE.—The false work consisted of pile and timber bents and 8x16-inch stringers. The bents were made long enough on the east side of the bridge to allow them to support a temporary foot walk fourteen feet wide outside of the traveler track, on which foot traffic passed during erection without passing under the new work. At the Allegheny end the walk was built far enough away from the bridge to allow the material to be hoisted between it and the bridge. This prevented any of the materials being hoisted over heads of foot passengers.

The pile driving for the false work was begun on June 10, 1892, and completed with the traveler erected on the Pittsburg end on August 10. In the false work were 800 piles and about 500,000 feet, board measure, pine timber.

The construction of the false work was as follows:—Piles were first driven, the length of piles being limited by the height of pile driver that could pass under the old bridge. They were driven so that the tops were about ten feet above pool level and capped with 12x12-inch timber. On the top of the caps was a second-story framed bent of 12x12 inches. These bents were of such a height that the floor of the old bridge could be blocked up and temporarily supported on these stringers.

A third story bent was then put up on each side of the old bridge to support the traveler tracks.

The foot travel was then turned on to the temporary foot-walk and the old sidewalks and hand rail torn out. The small wire ropes supporting the floor were removed, and the cables then had nothing to support other than their own weight.

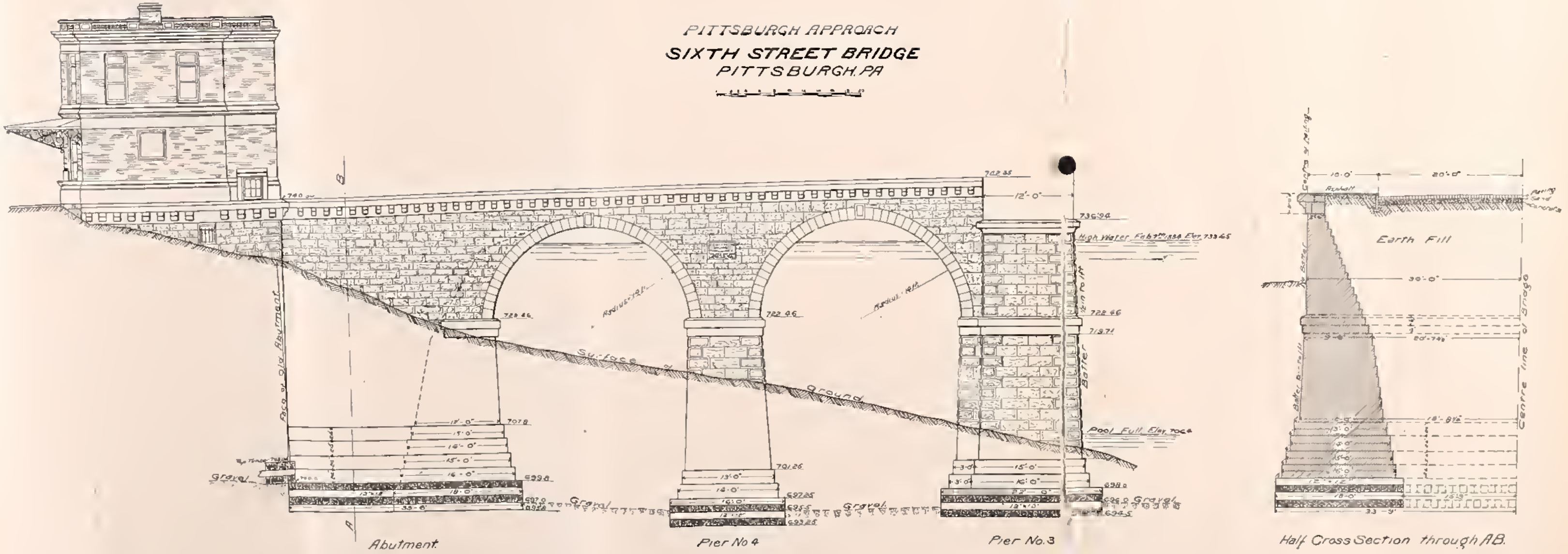
The outer longitudinal beams were removed, and also the parts of floor beams supporting the sidewalks. The floor beams were partially cut through the flanges next to the road-way with a cutter and sledge. A rope from the hoisting engine was hooked on to the outer end of the beam and the engine started. Before the beam was bent to a right angle it generally broke off. The work of taking down the cables followed. At the center of each span there were coiled around the cables two large chains eight feet apart. These chains were then connected together with block and tackle and hauled taut. When this was done about four feet of wrapping was taken off and the wires cut singly by hand with a wire cutter. The cables were cut in the middle of the two river spans and at the anchorages at the same time. When the block and tackle was removed the three pieces then hung loose and were lowered by the traveler to the floor of the bridge, cut in short lengths, and hauled away. The smaller cables were simply cut in the middle without any precautions for taking up the slack with chains and tackle as with the large cables. When all the wires but ten or twelve had been cut, these few wires held the cable together for about thirty seconds, when they parted by the strain in the cables. On breaking, the two ends separated about twelve or fifteen feet. The towers were taken down, and there was nothing left of the old bridge but the floor.

The next operation was blocking up the floor high enough to allow the third story bent to be erected under the old floor. This bent was the right height to allow the floor beams of the new bridge to rest on the stringers which were placed on the

caps. The old floor was then raised again and blocked up high enough to allow the floor beams to be inserted between it and the stringers. In raising the old floor hydraulic jacks were inserted under the longitudinal beams at three or four bents, and the floor lifted by them and then temporarily blocked up. In raising the floor care was taken at the ends not to raise it so high as to make such an abrupt change in the grade from the approaches that it would be impossible for the electric cars to get on the bridge. The jacks would then be taken to the next three bents and the floor raised over them and blocked up. When the entire floor had been raised the same amount, the operation would be begun again, and repeated till there was sufficient room for the new floor beams. This was accomplished, and the work of setting the floor beams, and stringing lower chord of Pittsburg span was begun on September 6th. On the 12th the erection of trusses was started, and on the 20th the blocking was knocked out and the span swung, so that the erection of the trusses for this span occupied eight days. This was accomplished on the Allegheny span in seven days.

On completion of the trusses, the old floor was lowered down on the new floor beams, the track at each end was cut, and the old floor slid over to the east side of the new bridge, tracks on approaches then slid over and connected up again with those on the bridge.

The shifting of the old floor on the beams of the new bridge was easily accomplished by the aid of hoisting engines. A chain was passed around one of the floor beams of the old bridge, to which a block was attached, and a second block was chained to one of the posts of the new bridge. The rope passing through these blocks was then led around one of the spools of the hoisting engine, the engine started, and the floor would be pulled over as far as it would go. The blocks and tackle would then be taken to the next post of new bridge, and the operation repeated.



PITTSBURGH APPROACH
SIXTH STREET BRIDGE
PITTSBURGH, PA
Surface of Ground
Face of Old Abutment
High Water, Feb 7th 1884 Elev. 733.65
Pool Full Elev. 706.4
Gravel
Batter
Earth Fill
Centre line of Bridge
Abutment
Pier No 4
Pier No. 3
Half Cross Section through AB.

PLATE 6.

The time occupied in getting the old floor up against the east side of the new bridge was only about one-half an hour.

The stringers and buckle plates on west side of the bridge, and the west permanent track, were next put in place and riveted. The paving between west truss and west track was laid, and temporary track on cross ties laid on top of the pavement. The tracks were cut again, and approach tracks pushed over and connected up with the temporary tracks.

The old floor was next torn out, and buckle plates and tracks were laid on the east half. The east track, on approaches, was then connected with east permanent track, and east temporary track removed; then the west track of approach was cut and connected with west permanent track, and the west temporary track torn out.

The entire time lost by electric cars, during the erection of bridge, was a little over three hours.

While the work was going on, the cars made better time than over the old bridge, for, on September 17, 1892, the Board of Directors suspended wagon traffic, and the cars were then no longer delayed by a slow team getting in front of them. Before the false works were removed, foot traffic was turned on to the east sidewalk.

During the entire time of erection the water was very low, and there was very little steamboat travel on the river. The only opening left for steamboats was the width of two panels of the new bridge. The traveler track was supported over this opening by plate girders, and the floor of old bridge was stiffened by trussing the 9-inch I beams.

During the erection many accidents happened, no less than thirteen workmen falling from false work or traveler, but none of them were dangerously hurt, and all recovered sufficiently to resume work again. Great credit is due Baird Bros., of Pittsburg, contractors for erection, for the skillful manner in which this part of the work was carried to completion.

Sidewalks and Paving.—The wearing surface of the sidewalks is Seyssel Rock Asphalt. The buckle plates were filled to the proper height with bituminous concrete, on top of which the asphalt is laid. When the west sidewalk was put down, the asphalt was continuous from end to end of superstructure. During cold weather it was found that the asphalt contracted more rapidly than the metal, and the result was numerous irregular cracks running across the walk. On laying the east sidewalk, joints were left at each panel point, and half way between, and the west sidewalk repaired and jointed in the same way.

The roadway of the approaches is paved with Ligonier blocks laid on 6 inches of concrete and 2 inches of sand. The joints are filled with pea gravel and paving pitch.

On the superstructure the foundation is concrete, made with cement and gravel, laid on top of the buckle plates. The top was brought to the proper form by templates, and smoothed off with trowels. The paving consists of white oak blocks, 5 inches deep, 3 inches thick, and 6 to 8 inches long. The blocks are laid in contact with the concrete without any sand cushion.

They were laid three-eighths of an inch apart, the spacing being kept uniform by three brads or tacks, which were driven through a template laid on the blocks. The template was three-eighths-inch steel, so that as the brads were driven through the holes they could not be driven more than three-eighths of an inch. The spaces were filled with Portland cement grout. Two inches were left at the gutters and filled with clay to allow for expansion.

The entire cost of the structure was $560,000.

Vehicle traffic was resumed on the bridge April 1, 1893, and has been constantly increasing ever since, and is now much greater than on the old bridge. It shows very little vibration, which is, in fact, imperceptible to one walking over it.

The bridge is what it was intended to be—simply an extension of the streets over the river, and no more restrictions are placed on traffic than on the streets.

There are, in the city limits, sixteen bridges crossing the Allegheny and Monongahela rivers, and there is not among them any finer specimen of a highway bridge, and the writer believes there are no better highway bridges of the same span in the country. The whole work reflects creditably on its designers and contractors.

The President—You have all heard the very interesting paper; has anyone anything to say regarding it?

Mr. Emil Swensson—I would like to ask Mr. Wilkins if he can explain the cause of blisters in the surface of the sidewalks?

Mr. Wilkins—That was the cause of much speculation and comment among engineers and contractors, and the only explanation I can give is that part of the asphalt was laid during frosty weather, and there was more or less frost left in the buckle plates. The heat from the smoke stacks of passing steamboats and locomotives going under the bridge transforms this into steam, which may cause the blisters.

Mr. Swensson—Another explanation of this matter has been given, which is as follows: Inasmuch as the surface of the buckle plates had at first been coated with coal tar, the absorbed heat and the heat from the steamboat smokestacks melts the tar, which then gives off some of its gases, which, of course, will endeavor to rise to the surface, and passes through the binder, but cannot pass through the asphalt surfacing. By the way, have any of the members heard anything about the newly-patented surfacing for bridge floors, etc.? It is called the Hay pavement, and is composed of hay or straw and cement, with a cement finish; has first been used somewhere in Philadelphia, and is now to be used on the new bridge over Harlem river in New York.

QUANTITIES IN SUBSTRUCTURE OF NEW SIXTH STREET BRIDGE.

Pieces.	Cu. Yds. Excav. under water.	Cu. Yds. Excav. above water.	Ft. B. M. Hemlock in place.	Ft. B. M. White Oak in place.	Lin. Ft. Piles Driven.	Lbs. Bolts and Spikes.	Cu Yds. Ranges Rock Masonry.	Cu. Yds. B'k'n Ranges Masonry.	Cu. Yds. Voussior Masonry.	Cu. Yds. Quoins.	Cu. Yds. Belt. and Coping Courses.	Lin. Ft. Cornice and Coping.	Cu. Yds. Filling.	Cu. Yds. Removing old Masonry.	Cu. Yds. Concrete.	Cu. Yds. Dredging.
Pier 1,	898	875	92,568				1,028			20	155			1,339		3,253
" 2,	2,688		197,189	2,984	5,951	2,675	1,720				70			1,465		2,565
" 3,	979	13	96,840				1,214			33	182			1,441		3,331
" 4,	864	457	69,192				564			16	70					980
Pgh. Abut'm't	960	2,700	125,136				932	1,215	303	1	46	198.0	1,523	92	218	
All'y "							44				43		54	250	111	
Totals,	6,389	4,045	580,925	2,984	5,951	2,675	5,502	1,215	303	70	566	198.0	1,577	4,587	329	10,129
Toll H'se, s.w.	219	857	20,640					356				49.5	633		91	
" s.e.		316			1,025			141				49.5	106		15	
" n.e.		281						140				49.5	112		52	
" n.w.		188						178				49.5	128		74	
Totals,	219	1,642	20,640		1,025			815				198.0	979		232	
Grand Totals,	6,608	5,687	601,565	2,984	6,976	2,675	5,502	2,030	303	70	566	396.0	2,556	4,587	561	10,129

Mr. Wilkins here exhibited a tracing showing the bridge as reinforced, and stated that he would like to ask Mr. Swensson why they put two girders there instead of one, to which Mr. Swensson replied that he did not know, unless they found that one was not sufficient and afterwards put in another, or that if the two had been made in one girder it would have projected further down than the required head room permitted.

Mr. Wilkins—The latter seems to be the best explanation.

A Member—In regard to the gravel foundations, I would like to ask if Mr. Wilkins or any of the members can tell anything about gravel causing vibration. A case I will mention is at H. K. Porter's mill. The ground there is all gravel, and an engine at the crossing some 700 yards distant will cause the whole place to shake.

Mr. Wilkins said that he did not see anything remarkable about that, and mentioned the fact that a train passing through the park would shake the foundation of the telescope on Observatory Hill.

Mr. Johnson, Swensson, and others here gave instances where the rumble of machinery and the passing of engines would cause the foundations and windows of buildings to shake, and where vibrations can be felt at considerable distances.

Mr. Scaife—Mr. Wilkins spoke about some of the timbers at the bottom when first brought out were in good condition and afterward exhibited evidence of dry rot. I would like to ask if they had been continuously under water. The idea has always been that timber under water can be preserved for a much longer period than out.

Mr. Wilkins—As long as they were under water they were all right, but after being taken out into the air they showed evidence of dry rot.

Mr. Scaife—That rotting was subsequent to taking out?

Mr. Wilkins—Yes.

Mr. Scaife—There is another question I would like to ask, and that is concerning the matter of crystallization. Were any experiments made with this metal which was taken out which would show absolutely that there was what we call crystallization in metal which had not been subjected to a strain above the elastic limit?

Mr. Wilkins—This crystallization was right above the nut, and by giving it one hard blow the nut would fly off. The fracture resembled No. 1 Bessemer pig.

The President—Were any of these rods broken elsewhere than at the nut, or did any other parts of the rod show evidences of crystallization?

Mr. Wilkins—No; none broken at any other place, showed crystallization.

Henry W. Fisher here mentioned the fact that the Standard Underground Cable Company had, at one time, shipped a carload of cable to San Francisco which showed crystallization in the lead, and, on seeking for a cause, the only reasonable theory was that the constant jar of the car in transit, causing vibration, had crystallized the material, and asked if any of the members had ever experienced the same trouble with shipments of iron or steel.

The President—I suppose that the process of crystallization—if it is a fact that it takes place in iron and steel—is too slow in its progress to be manifested so soon; and in the case of lead I should also anticipate the same thing there. If a two, three, or four weeks' journey across the continent would produce that effect it would be somewhat surprising.

K. F. Stahl here suggested that perhaps the lead was overheated; that lead, when overheated, will become fibrous, and that perhaps the jolting, or concussion, caused it to become crystallized.

The President—I would like to ask the gentleman if he can recollect any facts in connection with the working of that lead that would account for overheating?

Mr. Fisher—That question was considered at the time, but this lot was put on a special kind of cable—paper cable—and in paper cables you have to be careful not to have the lead too hot, because it would make the paper brittle, and we decided it could not have been that. The crystallization was exhibited most where the inside end of the cable came out. Now, at that point the rubbing or abrasive action of the adjacent convolutions upon the inside was most manifest, as was also the amount of crystallization. In New York we had trouble on the Elevated Railroad, and it could not have been from overheating, because the lead is put on in a semi-molten state.

Mr. Scaife—Why would it not be a good plan to suspend these cables on rubber or some elastic material to reduce the stress?

Mr. Fisher—That was considered some time ago, and steel springs are used because rubber will last but a very short time.

Mr. W. A. Bole here spoke about an experience which he had with a new bar of iron of good quality, which, when broken, had a crystalline appearance, and after heating and quenching in water without doing anything else to it the crystalline appearance was destroyed, and was almost as fibrous as a rope. He would like to know why heating the bar and throwing in water would cause such a change. Could not understand why heating a bar and quenching in water would make it soft, when they do the same thing to make it hard; why should it work both ways?

No satisfactory explanation was offered for this.

Adjourned at 10 P. M.

Daniel Carhart,
Secretary.

Allegheny, May 17, 1895.

Meeting of the Chemical Section.

The regular meeting of the Chemical Section was held in the Lecture Room of the Carnegie Library, Allegheny, Pa., on the above date.

The meeting was called to order at 8.15 p. m. by the Chairman, Mr. Jas. M. Camp, fourteen members and five visitors being present.

The minutes of the April meeting were read and approved.

The Committee on Chemical Literature called the attention of members to the following papers:

"A Reform in Chemical, Physical and Technical Calculations," by C. J. Hanssen, C. E., in the *Chemical News*, No. 1,845.

"Some New Laboratory Apparatus," by Ewald Sauer, in the *Journal of the American Chemical Society* for June, 1895.

Prof. Phillips, for the Committee on Methods, reported progress, a number of replies to circular letters sent out having been received by the committee.

Mr. Gustave Mueller, of the Duquesne Laboratory, read a paper on "Modern Processes of Vinegar Making."* The paper was discussed by Prof. Phillips, Dr. Stahl, Messrs. Garrigues, Stafford, the Chairman, and also by some of the visitors.

Adjourned at 9.45 p. m.

A. D. Wilkins,
Secretary C. S.

*The paper will be printed in the June number.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

JUNE 20th, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, June 20th, 1895, Thos. H. Johnson in the chair. The meeting was called to order at 8.25, 37 members and visitors being present.

The minutes of the last meeting were read and approved.

Dr. Stahl reported, as Chairman of the Reception Committee, that arrangements had been made for an excursion up the Monongahela river on the steamer "Elizabeth" on Saturday, July 6th, to leave about 1.30 P. M.

It was moved and seconded that the report of the committee be accepted and their action in the matter of the excursion approved by the Society. Carried.

The following resolutions were then adopted :

Resolved—That the Committee on Rooms be instructed to secure quarters for the Society in the business portion of Pittsburg for a term of three to five years, with a provision in the lease for either the purchase of said quarters at a sum to be stated in the lease, or for a term of three to five years without provision of purchase. The annual expense for quarters shall not exeed $900.

Resolved—That the action of the Committee on Rooms in the matter of securing quarters shall be subject to the approval of the Board of Direction, the latter being hereby empowered to have the proper officers of the Society execute such legal instruments as shall be necessary in the case.

Mr. Leon Le Pontois then read a paper entitled, "The Inefficiency of the Direct Methods of Converting Heat Into Electrical Energy."

THE INEFFICIENCY OF THE DIRECT METHODS OF CONVERTING HEAT INTO ELECTRICAL ENERGY.

The production of electricity directly from heat is a problem which has occupied the attention of many able electricians. Could the enormous energy latent in Solar heat be made to appear as electric energy, by means of a simple transforming apparatus, more efficient and less cumbrous than steam or gas engines driving dynamos, there is no doubt that great progress might be accomplished thereby, and that one of those grand steps of progress would be taken, of which the nineteenth century so justly boasts.

Unfortunately, it seems that there is no economical solution to the problem. Three quarters of a century have nearly elapsed since Seebeck discovered that by heating one of the junctions of a metallic circuit, consisting of two metals soldered together, an electric current was produced. The science of thermo-electricity thus originated has been developed by Becquerel, Pouillet, Pelletier, Mathiessen, Thomson, but these distinguished scientists and experimenters have never succeeded in producing an apparatus by means of which more than 2 per cent. of the heat energy could be converted into electricity.

Experiments have been made in another direction. Electricity has been obtained from heat by heating and cooling magnetic circuits in rapid succession, so as to modify their magnetic reluctance, thereby inducing alternating currents in coils surrounding such circuits. Thomson, Berlinor, Edison, Tesla, have devoted some time to this mode of conversion, and although such ingenious apparatus as the pyro or thermo magnetic generator have been the outcome of their work, as far as we know the efficiency obtained by this mode of conversion has never been superior, if equal, to the efficiency of the thermopile.

Can these persistent failures be attributed to the fact that such distinguished experimenters and scientists have not as yet struck the right process of conversion, or must we come to the

conclusion that after all the most economical solution to the problem lies in the construction of a more perfect heat engine driving the already highly efficient dynamo? My opinion is in favor of the latter mode of conversion, and I will endeavor to bring before you as clearly and briefly as I can, a few of the reasons on which my belief is based.

Let us consider first the case of the thermo-electric battery. Here is one of a very simple construction; it consists of a bar of bismuth bent twice at right angles, at the ends of which are soldered two copper strips which terminate in two binding screws connected to a galvanometer.

If one of the solderings is heated, the needle of the galvanometer is deflected, indicating the passage of a current from the heated to the cool junction; the deflection is greatly increased if the other junction is cooled at the same time.

Thermo-electric currents have long been attributed to an electromotive force produced by the contact of heterogeneous substances, a force which varies with the temperature.

Becquerel ascribed them to the unequal propagation of heat in the different parts of the circuit. He found that when all parts of a circuit are homogeneous, no current is produced on heating, because the heat is equally propagated in all directions. This hypothesis has been confirmed by many experiments showing that thermo-electric currents can be obtained in a monometallic circuit, when a source of heat is applied between two neighboring points of the circuit under different atomic structure.

We will now attempt to show how the unsymmetrical propagation of heat waves along a metallic circuit is attended by the manifestation of electric force.

But before going any further, I feel it my duty to tell you that the explanation I shall give of this phenomenon is not backed up by any scientific authority, and is rather a suggestion than an accepted explanation. I venture to bring before you the few ideas that I have on the subject, because they afford a

clear conception of the phenomenon, and that after all, if my understanding of the question is not the right one, thermo-electric phenomena might rationally be such as I suppose them to be.

I beg leave to remind you of two strange facts of the thermo-electric science which are known as the Thomson and Peltier effects.

Thomson found that when a wire, which is the seat of un-directional electrical disturbance, is heated, heat waves are not equally well propagated on both sides of the heated point; that is, the apparent conductivity for heat seems to be greater in one direction than in the other. Curiously enough, it happens that heat waves are more readily propagated in the direction of propagation of the electrical disturbance.

This phenomenon shows that there is a close relation between electricity and heat. Indeed, Hertz' experiments have demonstrated beyond doubt that light, heat and electricity, which have their origin in a vibratory motion of matter, are propagated by ether at an equal rate of speed. Moreover, Hertz has shown that an electrical disturbance, so improperly called "electric current," is not all propagated in the wire itself, but under all circumstances penetrates from without into the wire, and spreads into the metal with a comparative slowness. Now the electric force makes itself manifest by heating effects in the conductor, and more especially by a state of stress exerted in the medium surrounding the conductor, which stress is characterized by the magnetic properties exhibited by the medium.

The formation of this field of magnetic force is progressive, and is attended—while it takes place—with radiation of electric waves throughout the medium.

Now, if the formation of magnetic whirls around the conductor characterizes these long ether waves known as electric waves, why should not the propagation of these shorter ether

waves, called heat waves, along a conductor, be also attended with the formation of magnetic fields of force in the surrounding medium?

It seems pretty well established that the only difference existing between electric waves and light waves is solely a question of wave length. Both are electro-magnetic disturbances. Why not extend this appellation to heat waves which are much more likely to present the same characteristics as electric waves, by reason of their wave length, being much longer than the wave length of light waves? It is very likely that these three apparently different forms of energy—light, heat, electricity—are endowed with the same capacity of exhibiting effects which we attribute exclusively to electricity. The only reason why they do not apparently possess the same electric capacity must be attributed to the fact that the bodies which we consider as conductors of electrical energy (because they prevent it being dissipated) present great resistance to the propagation of the rapid vibration characterizing heat, and an almost insuperable resistance to the more rapid vibration causing on our retina the sensation of light.

Thus we see that the conductivity of a body, that is, the capacity that it possesses of preventing energy being radiated in the medium, can be defined as the readiness with which it takes up any vibrating speed differing from the constant speed of the universal atomic vibration.

If we introduce this hypothesis in the study of thermo-electric phenomena, their understanding becomes absurdly easy. Let us take up, for instance, the case of the Thomson effect. A conductor AB is the seat of an unidirectional electric disturbance of direction AB. A source of heat—say a Bunsen burner—is applied in C. The propagation of heat waves on both sides of this point will be attended with the formation of two thermo-motive forces equal and opposite. One of them will tend to decrease the original electro-motive force, the other will tend to increase it. Whatever be the value of the original

vector, as long as it is not zero, the thermo-motive force of direction BA will be decreased, while the thermo-motive force of direction AB will remain unaltered. Now, if the circuit is closed, it is obvious that the flow of heat energy in one direction will be greater than the flow of heat energy in the opposite direction. Thus heat is unequally propagated on both sides of the heated point.

The Peltier phenomenon is a consequence of the Thomson effect. When a current is propagated across the junction of two metals having different atomic structure, the junction is heated when the current is in one direction and cooled when it is in the other.

Let us consider two bars of antimony and bismuth AB, soldered together in C. When a current is propagated in the direction AB, the bars become unequally heated on account of the resistance of antimony being greater than the resistance of bismuth. This causes a difference of heat potential between the two metals, and heat waves are propagated from the antimony to the bismuth. According to what we have seen previously, the action of the current tends to direct the largest part of the heat towards the soldered point, therefore its temperature is higher than the temperature of any part of the circuit. If, now, the current is propagated in the direction BA, it can readily be seen that the result will be quite opposite, and that the point C will be the coolest point of the circuit. Allusion has already been made to thermo-electric currents produced when a circuit composed of two different metals has the two junctions unequally heated.

A variety of notions has been entertained by physicists as to the origin of thermo-electric currents.

They generally have been attributed to an electromotive force produced by the contact of heterogeneous substances, a force which varies with the temperature.

A few years ago, Dr. Oliver B. Ledge, the eminent English physicist, succeeded in a certain measure in demon-

strating the probability of this hypothesis—in the particular case of a copper iron couple heated at some temperature below 275 degrees C. But the same hypothesis is not verified in many other combinations. Besides, is that a clear explanation of what happens in a thermo battery; that is to say, that when two heterogeneous substances are placed in contact, one of them assumes the positive and the other the negative condition?

Becquerel ascribed them to the unequal propagation of heat in the different parts of a circuit. He found that when all parts of a circuit are homogeneous no current is produced on heating, because the heat is unequally propagated in all directions. But if uniformity of this is destroyed by cooling it in a spiral, or by knotting it, thermo-electric currents result from the unequal propagation of heat on both sides of the heated place.

As, however, Becquerel employed a red heat in his experiments, it is possible that the current obtained was due to a softening of a portion of the wire, while the knotted portion retained its hardness.

I made an experiment which tended to prove this. I had a copper ring about 10 inches in diameter, vertically mounted on a horizontal spindle. A little above the superior part of the ring a magnetic needle was delicately suspended by a silk thread and kept by the thread in the same plane as the ring. A Bunsen burner and air blast were placed so as to heat and cool simultaneously the lower part of the ring. Thus a portion of the ring was softened while the other was hardened. If, now, the ring was slowly rotated on its axis, the intermediate portion was heated, and the deflection of the needle indicated that a current was circulating through the ring from hard to soft. After a few moments the needle would come back to its former position, but if the ring was slowly rotated the defection of the needle was kept nearly constant, and the angle of deflection was maximum for a certain speed, which was about 50 revolutions per minute—the angle of deflection increasing

according to a parabolic function when the difference between the temperature of the hot and cool portions of the ring was increased.

I made some experiments with a view of increasing the efficiency of the apparatus. I used a series of rings 1-100 inches thick, coated with lamp-black and separated by small washers. The rings were mounted on iron spiders, and when they were set in rotation the spider and the shaft were very thoroughly magnetized—the plant efficiency was of course considerably increased, but the economical efficiency was practically the same; as in the former experiment, and as far as I could ascertain, it was about 1 per cent., or nearly so.

This experiment seems to demonstrate that Becquerel's hypothesis is based on facts.

The unequal propagation of heat in a metallic circuit may be caused by differences in thermal conductivity—by unequal decrease of temperature on both sides of the heated place.

It may also be caused by differences in the specific heat of the two metals, or at two neighboring parts of the same metal, but whatever is the reason on account of which, heat is unsymmetrically propagated on both sides of a heated point; it seems to me, that the explanation of the phenomenon could be found in analyzing carefully these different causes.

I picture to myself what is going on inside a thermopile as follows: The propagation of heat waves on both sides of the heated point is always attended with electrical displacements in the surrounding medium, which affects more or less the inside of the conductor.

If the circuit is homogeneous, the resultant of the electric force is zero, but if such is not the case, the resultant is something different from zero, and an unidirectional electrical disturbance or current takes place inside the conductor.

Now, it is obvious that the dissipation of a certain amount of heat energy in a thermopile must be attributed to a loss by

radiation or convection, and to the absorption of heat energy in the atomic motions which determine the manifestation of electric force.

The thermopile may be considered then as an imperfect heat engine working between two temperatures, and its theoretical efficiency calculated as follows :

Let t and t_1 represent the temperatures of the hot and cold junctions ; e the E. M. F. per degree Centigrade. The total E. M. F. will be represented in this case by $E=e\ (t-t_1)$ and the current by $C=\frac{e\ (t-t_1)}{R_1+R_2}$, R_1 and R_2 representing the internal and external resistances.

According to a well-known law of electrodynamics, the efficiency of a battery is maximum when the internal resistance is minimum while the external resistance is maximum. Thus in the particular case of the thermopile, the efficiency depends directly on the specific resistance of the metals used. By looking over the following thermo-electric series, we can see that by choosing badly conducting metals, such as bismuth and antimony, or still better,

Bismuth,	Tin,	Zinc,	Iron,
Cobalt,	Copper,	Cadmium,	Red Phosphorus,
Potassium,	Silver,	Strontium,	Antimony,
Nickel,	Platinum,	Arsenic,	Cellurium,
Sodium,	Gas Coke,		Selenium,
Lead,			

Selenium and Tellurium, the efficiency is greatly increased ; chosing non-conductors it becomes enormous, but when one uses non-conductors we cannot expect to excite currents flowing in closed circuits ; we can only expect electrostatic forces.

It seems to me that the best way to treat the problem is to consider the case in which the external work done by the battery is maximum and calculate the efficiency corresponding to that maximum, the maximum work of a battery is obtained when the internal resistance is equal to the external resistance,

then we will have $W = \frac{e_2(t-t_1)^2}{2R_1} - \frac{e^2(t-t_1)^2}{4R_1} = \frac{e^2(t-t_1)^2}{4R_1}$ which expresses the value of the minimum work.

The internal resistance depends on the dimensions and the specific resistance of the bars constituting the battery.

Let r_1 and r_2 represent these specific resistances, and s_1 and s_2 the sections of the bars, having a length L.

We shall have $R_1 = L\left(\frac{r_1}{s_1} + \frac{r_2}{s_2}\right)$

The external work per second is, therefore,

$$W = \frac{e^2(t-t_1)^2}{4\,L\left(\frac{r_1}{s_1} + \frac{r_2}{s_2}\right)}$$

Now let us compare this useful work to the energy wasted by the ordinary conductivity of heat along the bars.

If we represent by Q the amount of heat propagated and $r1^1$ $r2^1$ the thermic resistances of both metals, we have $Q = (t-t_1)\left(\frac{s_1}{r_1{}^1L} \div \frac{s_2}{r_2{}^1L}\right)$

The amount of heat energy, furnished at a temperature t, which can be transformed into mechanical work by a perfect heat engine, working with a temperature difference $t-t_1$, is $\frac{t-t_1}{t_1}$

Therefore the heat lost per second will be in our case $\frac{J(t-t_1)^2}{tl}\left(\frac{s_1}{r_1} + \frac{s_2}{r^1_2}\right)$, J representing the mechanical equivalent of heat.

The relation existing between this wasted energy and the useful work is $\frac{4J}{te^2}\left(\frac{r_1}{s_1} + \frac{r_2}{s_2}\right)\left(\frac{s_1}{r_1^{\ 1}} + \frac{s_2}{r^1_{\ 2}}\right)$ an expression which is absolutely independent of $(t-t_1)$ and of L.

The resistance being given, $\frac{s_2}{s^1_1}$ must be determined so as to make $\frac{s_2}{s_1}$ a minimum this condition is fulfilled when

$\left(\frac{s_2}{s_1}\right)^2 = \frac{r_2}{r_1} + \frac{r_2^1}{r_1^1}$ thus the expression giving the efficiency corresponding to the maximum work bcomes $\frac{4J}{tL_2}\left(\sqrt{\frac{r_1}{r_1^1}} + \sqrt{\frac{r_3}{r_1^2}}\right)^2$

I have applied this formula to the case of German silver, Iron Couple, and found for the value of the efficiency corresponding to the maximum work, 1,358 per cent.

Of course, I do not give this value as being absolutely correct, for the exact determination of the specific resistance is an extremely difficult operation.

However, I believe that this value is about correct, for I have made similar measurements on a copper iron couple and obained nearly the same results.

Two characteristic figures enable us to compare the efficiency obtained by the direct method of conversion through the thermopile and the efficiency obtained by driving a dynamo by means of a gas engine.

The Clamond Carpentier thermo-electric battery, which is recognized as being the most efficient, consumes 25 cubic meters per kilowatt hour. A good Otto gas engine driving a dynamo spends about 1.35 cubic meters per kilowatt hour. Hence the thermo-electric battery, to produce an equal quantity of available electric energy expends nearly eighteen times as much heat energy as the gas engines directly driving the dynamo.

THE PYRO-MAGNETIC GENERATOR MOTOR.

It has long been known that iron remains magnetic at red heat, above which point it somewhat suddenly ceases to be magnetic and remains at a higher temperature non-magnetic. This important fact was discovered by that pioneer in electricity and magnetism, Dr. Gilbert. He first showed that a loadstone and a piece of iron equally lost their power of affecting the magnetic needle when heated very hot, and noticed that the magnetic property returned to the iron after it had cooled

a little, but that the natural magnetism of the permanent magnet is altogether destroyed. Faraday was the first to discover that there was a critical temperature at which steel magnets lose their magnetism, this temperature varying according to the hardness and structure of steel. This phenomenon has been investigated by quite a number of distinguished electricians, such as Prof. Elihu Thomson, Dr. Hopkinson, and experiments made on different samples of iron, steel and nickel have established the most remaikable fact that at a temperature of 770° C. the magnetization of iron is 11,000 times as great as that of substances which we are accustomed to consider as non-magnetic. At a temperature of 785° iron is practically non-magnetic ; that is, presents an extremely high magnetic reluctance. These changes are shown by this diagram. It seems that the effect of rise of temperature is to diminish the maximum magnetization of which the body is capable—slowly at first, rapidly at the end. It also very greatly diminishes the coercive force and increases the facility with which the body is magnetized. The critical temperature at which magnetism disappears changes rapidly with the composition of steel. For very soft charcoal iron wire the critical temperature is as high as 880° C. ; for hard Whitworth steel it is 690° C. This curious property of iron has been utilized in the construction of apparatus for converting, directly, heat into electricity or motive power.

As far back as 1868 Dr. Gore brought before the Royal Society of London an apparatus in which the principle of the thermo-magnetic generator is fully exemplified. A straight wire of soft iron was placed in the field of a permanent magnet so as to better the magnetic circuit. The wire was fastened by its extremities to two binding posts connected to a circuit including a contact breaker and a battery. A coil of fine wire connected to a galvanometer was wound on a thin glass tube surrounding the iron wire. On sending the current of the battery through the iron wire the latter was heated, its mag-

netic reluctance increased thereby, and the number of lines of force threading through the coil being altered, current was induced in the coil as shown by the deflection of the galvanometer needle.

On disconnecting the battery, thereby cooling the iron wire, a reversed direction of induced current was produced. No induced current occurred by heating the iron wire if the magnet was absent, nor was any induced current obtained if the magnet was present and wire of copper or German silver were heated to redness instead of iron wire. It is evident, therefore, that the variation in the magnetic reluctance of the iron wire was the cause of the phenomenon.

In 1879 Prof. E. J. Houston and Elihu Thomson devised a very curious thermo-magnetic motor. This motor, though devoid of practical value, is of sufficient scientific interest to warrant a description: A ring of thin steel was mounted on an axis, so as to be quite free to move, the edge of the wheel being placed opposite the poles of a magnet. The ring being placed at an equal distance from both poles, the lines of force distribute themselves symmetrically on each side of the ring, and the magnetic reluctance of the circuit is minimum under the existing conditions.

If, when the disc is heated at one of the extremities of the diameter, A A_1—B B_1, at the extremity A, for instance, the reluctance of the heated part of the ring increases, a lateral pull is exerted on the axis, but no rotation takes place, because the resultant of the force exerted by the magnet on the disc passes by the center of the latter.

If, now, the heat is applied at some points 45 degrees apart from A or A^1 the field tends to rotate the ring about its axis in order to allow of an even distribution of the lines of force through the iron, corresponding to a minimum magnetic reluctance. If the source of heat be kept at the same place, and if the disc is thin enough to cool up rapidly, it can be readily seen that the distribution of the lines of force will be

constantly modified and that permanent rotation will result of the constant tendency of the field to keep down its reluctance.

By means of this little motor mechanical energy is directly obtained from heat, but its efficiency is vanishingly small, for reasons that we will show later on.

In a paper read in 1887 before the American Society for the Advancement of Science, Thomas A. Edison described the principle and mode of action of his new machine for converting heat into electricity—the pyro-magnetic generator (such was the name given by Edison to his invention) excited great expectation at first, but in despite of the great inventive ability of the greatest of modern inventors, the efficiency of this machine has never, as far as I know, exceeded 2 per cent., and the original model is now relegated to the scrap in the cellar of Edison's laboratory.

The pyro-magnetic generator is based on a principle quite similar to the thermo-magnetic motor of Prof. Thomson, but while the latter is a mere toy, the former is a very ingeniously designed machine from a scientific as well as from an engineering point of view. Indeed the pyro-magnetic generator could not be much improved upon—and the reasons for its efficiency do not lie in an imperfect application of the principle discovered by Gilbert, but in the fact that all apparatus based on similar principle are bound to be inefficient (ipso facto).

The pyro-magnetic generator motor has many points of resemblance with the ordinary dynamo—in fact it is a dynamotor, provided with an armature looking somewhat like a squirrel cage, rotating in a magnetic field. The armature consists of eight hollow iron cores, constructed of corrugated sheet iron covered with asbestos and wound with wire. These are held in place by two circular iron plates, through the center of which runs a shaft carrying at its lower extremity a semi-circular shield of fire-clay, called a guard-plate, which covers the ends of four of the armatures. The field is made of wrought iron pole pieces, bent in a U, between the lips of which the iron

cores are rotated. The shaft carries a cylinder of insulating material, having metallic contact pieces let into on opposite sides, the line joining them being parallel to the straight edge of the guard-plate. Upon this cylinder eight springs press, each spring being connected to the end of one of the armature coils. The springs are so adjusted that each of them comes into contact with its metallic segment just as the preceding coil of the pair to which it is connected is uncovered by the rotation of the guard-plate. Upon the same shaft and above the cylinder just mentioned, a pair of metallic rings are placed, insulated from the shaft, to each of which one of the metallic segments is connected. Brushes pressing upon these rings take off the current produced by the generator. The entire machine is placed upon the top of a furnace, fed by a blast, so that the products of the combustion are forced up through the interstitial cores which are not covered by the guard-plate, and raise them to a high temperature. On rotating this plate the cores are successively uncovered on the one side and covered on the other, so that continually during the motion the magnetic reluctance of four of the coils increases, while the magnetic reluctance of the other four decreases—hence the armature is constantly rotated; and the variations in the number of lines of force threading through the coils varying according to the reluctance of the cores on which they are wound; alternating currents are set up in the moving coils, and they are rectified by the commutator.

A study of the principles involved in this machine show us that there is a practical limit to the E. M. F. that can be induced with a given field magnet. The E. M. F. is, as you know, proportional to two factors—the magnetic induction, or the number of lines of force which is theoretically unlimited since the field magnets can be made of any size, and the speed at which the armature cuts the lines of force.

In the case of an ordinary dynamo, this speed can be as high as wanted, but in the case of the pyro-magnetic generator,

this factor depends essentially on the speed at which the magnetic reluctance of the iron can be modified by heat. Edison has found by experiment that 120 heatings per minute are about the fastest rate at which these changes can take place. This means that the lines of force of the field can be cut 240 per minute, while in a dynamo running at the moderate speed of 1,200 revolutions, they are cut 2,400 times per minute. This means that for a given weight of wire on the armature, the field magnet should be ten times as powerful as in an ordinary dynamo.

Hence the pyro-magnetic generator must be quite large in comparison with the ordinary dynamo.

Another bad feature of this machine is that the iron cores which are to be heated and cooled so rapidly must be made of very thin metal, and as they have to be brought to a high temperature in order to modify their reluctance, it is evident that a rapid oxidation and disintegration of the metal takes place which would seriously affect the life of these parts of the machine.

Both of these features are not, however, an insurmountable obstacle, and affect but very little the efficiency of the machine.

As in all heat engines, the efficiency of this motor depends upon the temperature difference in working—the rate of temperature variation—and upon the proximity to the points of maximum effect.

No advantage will be gained by raising the temperature of the heated portion above the point at which its magnetic reluctance is maximum, or practically zero, nor on the other hand would it be advantageous to cool the part between the screens below the point where its magnetic reluctance is practically a minimum.

From the inspection of the curve showing the relation between heat and the magnetic reluctance of iron, we see that in order to get the best results the difference of temperature working should not be greater than 15 degrees Centigrade.

The efficiency of the pyro-magnetic generator motor should not be lower than the efficiency of an ordinary dynamo motor, if we consider it as an electric generator—but the reason for its inefficiency as a whole, must be attributed to the fact that it is nothing else but an ordinary dynamo directly driven by a very inefficient heat engine. If we consider that the specific heat of magnetized iron is greater than that of unmagnetized, it follows that the difference is evidently that which may be converted into motive power.

We have seen that the best range of working is between the temperatures of 785 degrees Centigrade and 770 degrees—if we apply to the case the formula of Carnot $\frac{To-T_1}{To}$ equals efficiency, we obtain 1.9 per cent. as *theoretical efficiency.*

If it were possible to limit the heating and cooling in such a way that the greater part of the heat actually consumed could be the difference in *specific heats*, then the efficiency of the machine might be increased, but this is obviously impossible.

As far as 1885, Berliner obtained alternating currents from a stationary coil wound upon a hollow iron core, which was part of a magnet circuit, the heat of a furnace or a cold blast of air that was successively sent through the core, causing variations in its reluctance, and thereby currents were induced in the coil.

Tesla has made numerous experiments in the same field, causing small iron armatures to oscillate in front of magnets. In some cases he obtained direct rotation, but these experiments are of secondary interest, because they had already been made long before him by Gore, Thomson, Cooper, Berliner.

Tesla's thermo-magnetic generator is practically based on the same principle as Berliner's, but differs from the latter by details of construction, which improve greatly the plant efficiency of the machine. Besides, the products of the combustion, after having heated the iron, are directed under a small boiler placed on the top of the apparatus, and the steam gen-

erated is sent through the tubes instead of an air blast. The use of steam as a cooling device is original, and in a certain measure, effective, for it diminishes considerably the oxidation of the iron tubes, and thereby increases the life of the machine.

However, the efficiency of this thermo-magnetic generator is not superior to the efficiency of the pyro-magnetic generator, because both apparatus, being based on the same principle, work between the same limits of temperature, and are, ipso facto, inefficient.

From the unsuccessful experiments made in this fascinating field by distinguished inventors and scientists, and possibly from the few remarks which I have had the honor to bring before you, we may conclude that it is not very likely that electricity will ever be obtained, efficiently, from heat. By the word "Electricity," I have reference to those long ether waves by means of which we manufacture light and transmit energy to great distances over wires.

A time may come when the beautiful system of lighting and power transmission by means of currents of high potential and frequency, devised by Nikola Tesla, will be as practical as it is efficient; then we might succeed in obtaining the considerably shorter electric waves used in that system direct from heat.

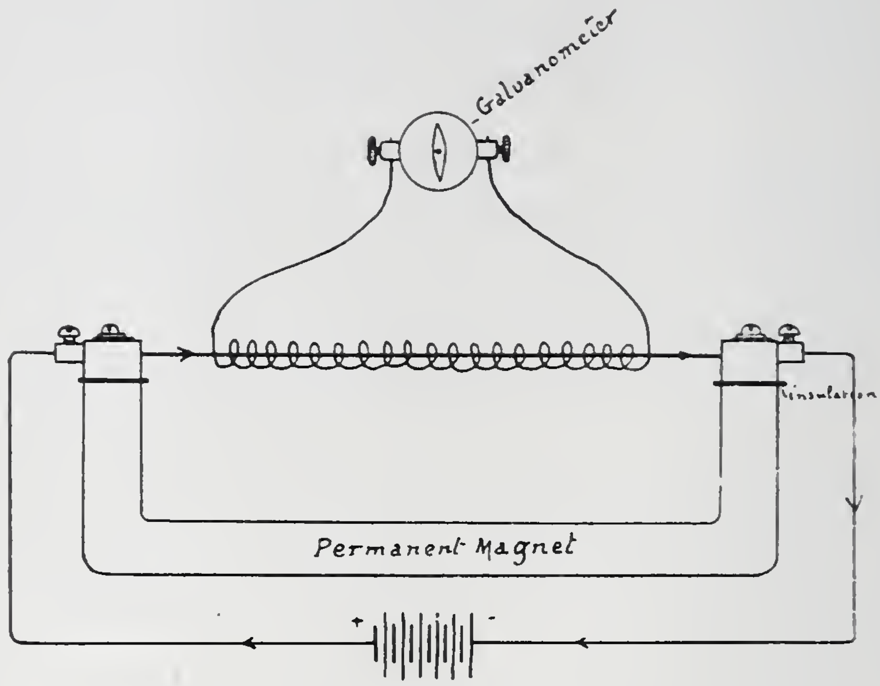
This is, however, a dream of the future that may never be realized—and while we are confronted with the necessity of obtaining electricity as economically and simply as possible, it seems to me that the commercial solution most promising of success is to improve the gas engine, and harness it to the highly efficient alternating current dynamo.

In conclusion, allow me to thank you most heartily for your kind attention, and may I be permitted to express the hope that my reasoning has proven sufficiently clear and logical for you to agree with me that in the generation of electricity, at least, "the longer way round is the shorter way there."

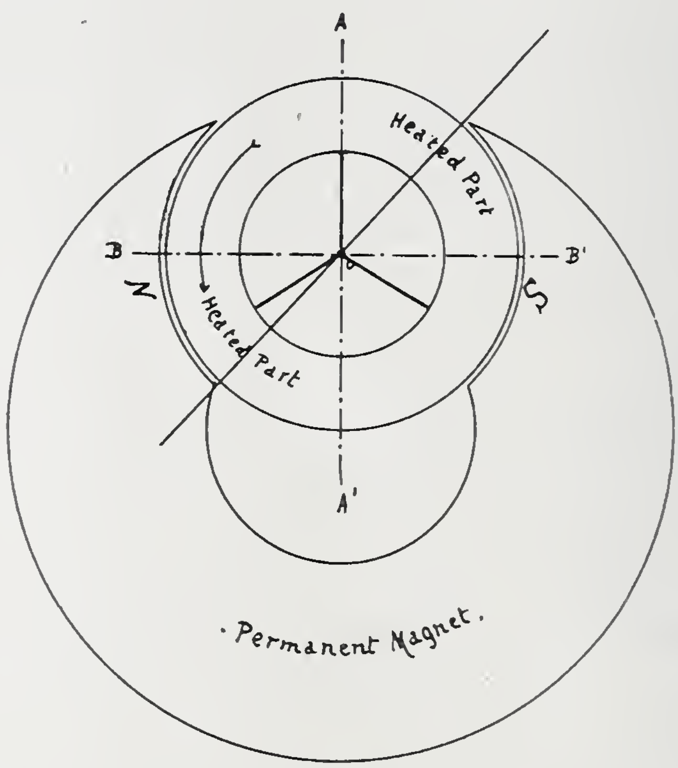
Mr. Koch said he was glad to see in Mr. Pontois' paper a complete vindication of the truth of Faraday's and Clerk-Maxwell's teachings, from which scientific men had strayed too long.

It was moved and seconded that, as the subject of this paper is one of too great importance to be passed over hastily, the discussion be taken up and continued at the next meeting. Carried. Adjourned.

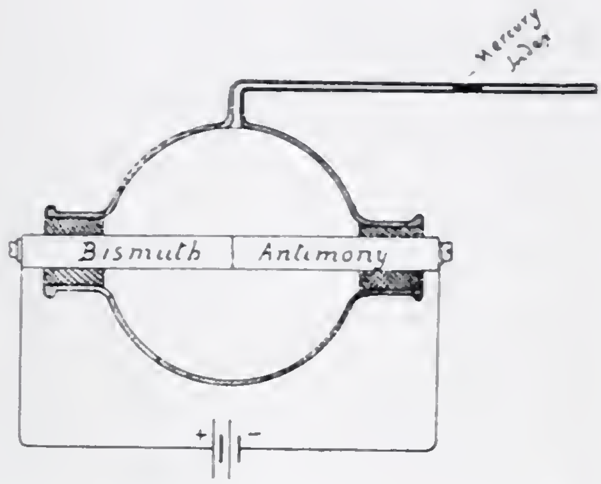
DANIEL CARHART, *Secretary.*



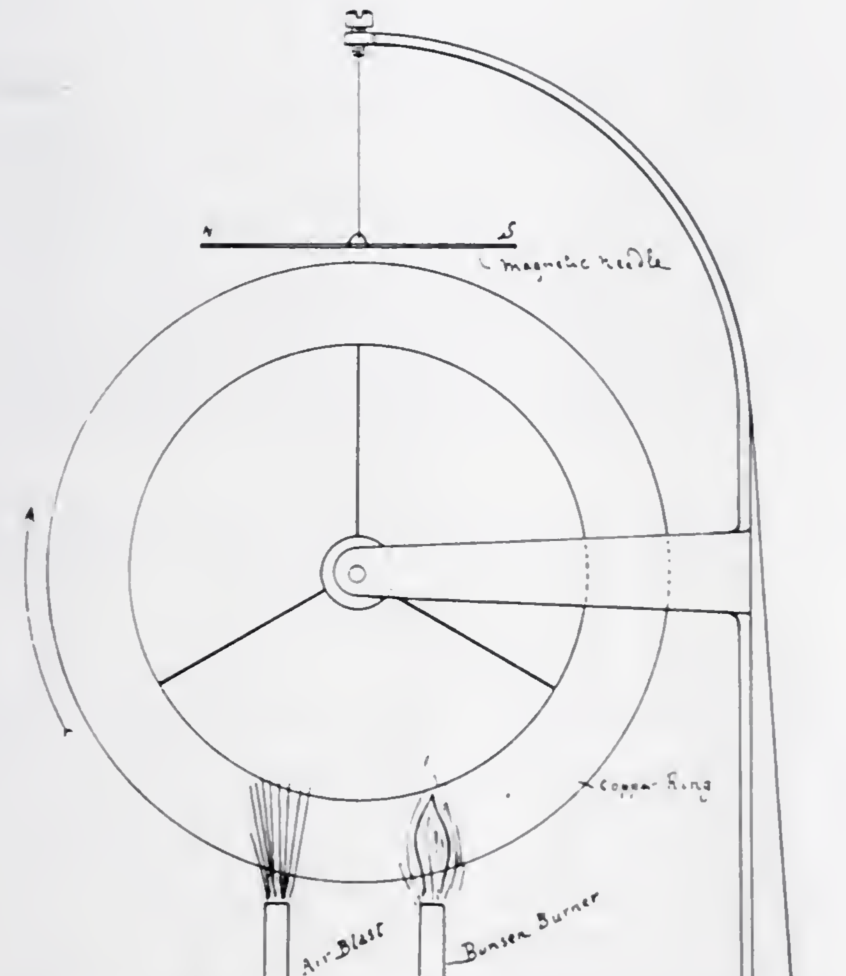
Gorre's Thermo-Magnetic Inductor



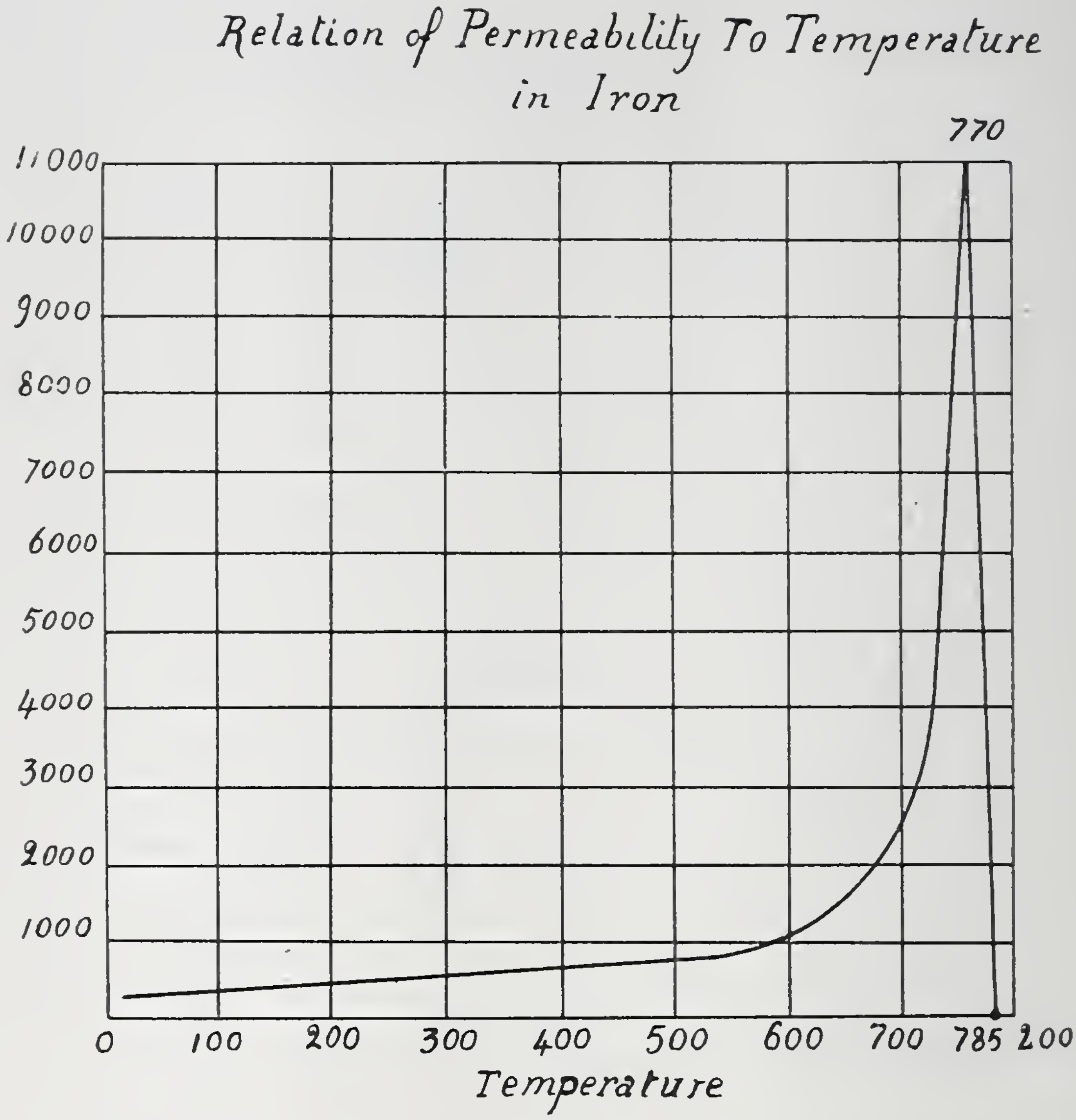
Prof: Houston's Thermo-Magnetic Motor.



Apparatus for Demonstrating the Peltier Effect



Thermo Electric Generator


Relation of Permeability To Temperature in Iron
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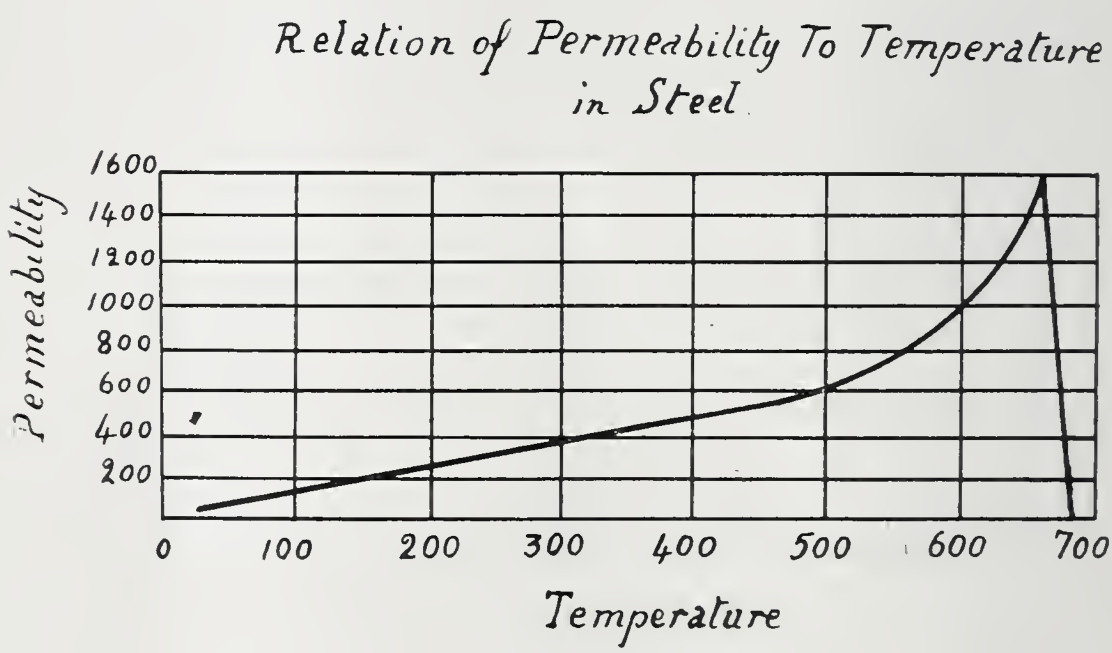
Relation of Permeability To Temperature in Steel
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Temperature

MINUTES OF CHEMICAL SECTION.

ALLEGHENY, PA., June 21, 1895.

The regular meeting of the Chemical Section was held in the Lecture Room of the Carnegie Library Building on Friday evening of the above date.

The meeting was called to order at 8 P. M. by Chairman J. M. Camp, ten members being present.

The minutes of the last meeting were read and approved.

The Committee on Chemical Literature called the attention of the Society to the following articles:

"Determination of Tar and Tar Acids in Wood Preservatives," by Dr. C. B. Dudley and F. N. Pease, in American Engineer and Railroad Journal for June, 1895.

"The Qualitive Separation of Metals of the Iron Group," by C. L. Hare, in The Journal of the American Chemical Society for July, 1895.

"The use of Sodium Peroxide for Oxidation at a Red Heat," in The E. & M. Journal for June, 1895.

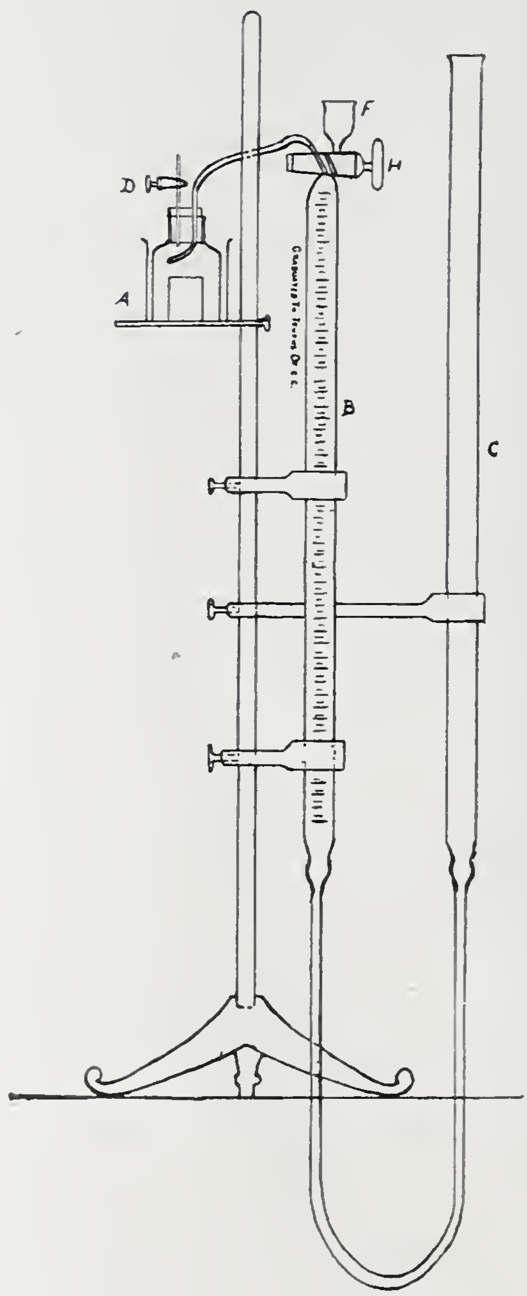
The following paper, by Mr. Theo. W. Friend, of the Clinton Iron Works, was then read by Prof. F. C. Phillips:

A REVIEW OF SOME RECENT APPLICATIONS OF THE NITROMETER,

BY THEODORE W. FRIEND, PH. B.

W. Knop described in the Chemisches Centralblatt for 1860, p. 244, a method of analysis based upon the measurement of a gas set free in a given chemical reaction. This author proposed to determine nitric acid by observation of the volume of hydrogen evolved from sodium hydroxide by a known weight of aluminum in presence of a nitrate in solution, as compared with the volume produced by sodium hydroxide and alumnum alone. The same author (Zeitschrift für Anal. Chemie, 1875, p. 247) showed that ammonia might be determined by measuring the nitrogen set free from an ammonium compound by the action of alkaline sodium hypobromite solution.

In more recent times it has been recognized that the exact quantitative relationship existing between some one or more of the constituents of a compound and the volume of the gas evolved in a particular reaction may be made the basis of a variety of analytical methods. In the Berichte der Deutschen Chemischen Gesellschaft, 1878, p. 434, Lunge proposed a simple and useful form of apparatus, which he called a nitrometer, for the determination of nitric acid. The concentrated solution of the nitric acid was brought into contact with mercury in presence of sulphuric acid. From the volume of the nitric oxide gas produced the quantity of the original nitric acid was calculated.



The apparatus, as originally used by Lunge, consisted of a graduated eudiometer, provided above with a funnel through which the reagents were introduced, while the lower end was connected by rubber tubing with a reservoir which could be raised or lowered so as to bring the liquids in both tubes to the same level.

The nitrometer, in its various forms, can be used for the analysis of many different compounds. Most of the improvements were made by Lunge.

A convenient form of instrument consists of a gas generator A, connected by a three-way stop-cock with the eudiometer B. A reservoir, C, is connected with the lower end of B by rubber tubing. The generator has an inner and outer well. The stop-cock D is opened when the stopper is placed in the bottle, to equalize the pressure. The eudiometer is filled by raising the reservoir C and allowing the water (or mercury) to partly fill the funnel F. When the eudiometer is filled the stop-cock H is turned to connect the generator with the eudiometer.

When all the gas is given off the liquid in the reservoir is brought to the same level as that in the eudiometer and the volume observed.

From a reading of the barometer and thermometer it is then easy to calculate the normal volume of the gas, and from this the determination is made. The method is mainly applicable to cases where a considerable volume of gas is evolved rapidly and without appreciable rise of temperature.

Among the reactions which are especially suited to the nitrometer method must be cited the large class of cases in which hydrogen peroxide on contact with various oxygen compounds of metals causes reduction to a lower oxide, being at the same time itself reduced, with evolution of a volume of oxygen equal to that lost by the metal. Changes of this type are so numerous that hydrogen peroxide has become a very important reagent in nitrometer work.

Recently there have been many contributions to the literature of peroxide of hydrogen, from which the following statements have been taken :

Peroxide of hydrogen was discovered by Thenard, in 1816. It is a colorless transparent liquid, without taste. Its specific gravity in concentrated form is 1.452. It does not freeze at —30° C. It can be mixed in all proportions with water.

Peroxide of hydrogen, as usually sold, is very unstable. Experiments by Wolfenstein (Ber. d. Chem. Gesell., 1894, p. 3307,) confirm the views of other chemists that its instability is mainly due to the presence of traces of salts of heavy metals and of alkalies.

Wolfenstein has shown that it may be concentrated by evaporation at 75° C, and that by heating to 85° C, under a pressure of 65 millimeters of mercury its strength may be increased to 45 per cent. of H_2O_2, yielding then a somewhat syrupy liquid. The commercial peroxide of hydrogen usually contains minute quantities of free mineral acids which possess a preservative action.

One of the most curious properties of peroxide of hydrogen is its action as a reducing agent ; as when permanganate of potassium and water are mixed with peroxide of hydrogen and dilute sulphuric acid, oxygen is given off and the permanganate of potassium is bleached.

Carrara has verified by determination of the depression of the freezing point of its solution, the molecular weight of peroxide of hydrogen to be H_2O_2. (Ber., 1892, p. 901, R.)

Peroxide of hydrogen is decomposed in unlimited quantities by potassium dichromate, but converts chromic acid in presence of sulphuric acid into the blue compound, Cr_2O_7, which is afterwards reduced to chromic oxide.

The hydrogen peroxide used in all the following experiments was of such strength that 1 c. c. of the fluid contained about 13 c. c. of available oxygen.

APPLICATIONS OF THE NITROMETER METHOD.

Metals of Group I.

Peroxide of hydrogen exerts a reducing action upon ferricyanide of potassium in presence of an alkali with evolution of oxygen. $K_6Fe_2Cy_{12}+2NaOH+H_2O_2=K_6Na_2Fe_2Cy_{12}+2H_2O+(O—O)$.

As in many other cases one-half of the oxygen comes from the peroxide of hydrogen, while the other half comes from the decomposition of the potassium ferricyanide.

Quinke (Zeit. Anal. Chem., 1892, p. 1,) has based a method for the determination of a caustic alkali upon this reaction, this author having shown that the volume of oyxgen evolved here is directly proportional to the quantity of alkali present in solution.

In order to study this method, I have tried the following experiments :

For the purpose in view peroxide of hydrogen in a state of purity is necesssary. As all commercial peroxide of hydrogen contains small quantities of free acid, and as can be readily seen, any free acid would give low results, the peroxide of hydrogen to be used must be first rendered neutral.

A small quantity of barium carbonate was added to the peroxide of hydrogen, which was then well shaken and allowed to stand twenty-four hours. It was then filtered through asbestos. If, after filtering, the peroxide shows an alkaline reaction a very small quantity of sulphuric acid must be added, and after the precipitate has settled the fluid again filtered.

The best results in the determination of alkalies were obtained by placing the mixture of alkali to be determined with an excess of potassium ferricyanide in the outer well of the gas generator, while from two to three c. c. of peroxide of hydrogen were placed in the inner well.

The gas generator was then shaken to thoroughly mix the fluids and drive over the gas. When all the gas was expelled, the generator was immersed in water at the temperature of the

room and allowed to stand ten minutes. It was then taken out and shaken to insure the complete expulsion of the gas, again placed in water and allowed to remain ten minutes.

The volume of gas was then observed, reduced to O° C and 760 mm. pressure, and by multiplying this volume by the coefficient given below, there was obtained the number of milligrams of alkali in the solution.

For these determinations I used a solution of sodium hydroxide, the strength of which was determined by standard sulphuric acid solution, and found to contain in one c. c. 8.42 milligrams of sodium hydroxide.

In all the following experiments, the atomic weight of oxygen was taken as 15.96, and that of sodium 22.995.

As will be seen by the equation given above, one molecule of sodium hydroxide evolves one atom of oxygen, or 39.955 parts by weight of sodium hydroxide evolve 15.96 milligrams of oxygen. 15.96 milligrams of oxygen are by the proportion; $1.42908 : 1000 :: 0.01596 : \times = 11.168$ cubic centimeters, or one cubic centimeter of oxygen equals 3.57763 milligrams of sodium hydroxide.

The nitrometer method involves the reduction of gas volumes to normal conditions, and much time is saved in the calculations by the use of an instrument originally proposed by Kreusler (Ber. d. Chem. Gesell., 1884, p. 29), but modified by various authors.

The original form of apparatus described by Kreusler is probably the most convenient for ordinary nitrometer work.

It consists of a form of eudiometer closed above and below by stop-cocks and connected below with a level tube holding water. It is filled once for all with exactly so much air at an observed temperature and pressure as would occupy 100 c. c., if measured dry at O° C and under 760 mm. mercury pressure. To reduce any gas volume to normal conditions a reading of the volumeter is first made. Suppose the reading to be 112.5

c. c. The volume of the gas is then to be multiplied by the fraction $\frac{100}{112.5}$ in order to ascertain the normal volume measured dry.

1 c. c. NaOH contains 8420 mg., NaOH.

Experiments.	Reading of Volumeter.	C. c. of NaOH used.	C. c. of Oxygen obtained.	C. c. of Oxygen at 0°C. and 760 mm.	Amount of NaOH found by Nitrometer. Mgs.	Amount of NaOH found by titration with H_2SO_4. Mgs.	Difference. Mg.
1.	110.40	5.02	13.00	11.775	42.126	42.268	—.142
2.	111.00	9.73	25.35	22.83	81.677	81.926	—.249
3.	111.30	20.16	52.80	47.44	169.720	169.74	—.02
4.	111.70	12.80	33.75	30.214	108.094	107.776	+.318
5.	112.00	15.01	39.80	35.53	127.113	127.384	—.271
6.	113.50	14.57	39.00	34.36	122.927	122.679	+.248
7.	113.60	9.95	26.54	23.36	83 573	33.779	—.206

Quincke (Zeitschrift für Anal. Chemie, 1892, p. 12) proposed the use of the method for the determination of potassium hydroxide. In order to study this application of the method I prepared a solution of potassium hydroxide containing in 1 c. c. 9.689 milligrams of KOH, as shown by a determination by standard sulphuric acid. The experiment was tried as in the case of the determination of sodium hydroxide. The reaction is as follows :

$$2K_3FeCy_6 + 2KOH + H_2O_2 = 2K_4FeCy_6 + 2H_2O + O_2.$$

As will be seen from the above equation one molecule of potassium hydroxide evolves one atom of oxygen, or 55.99 milligrams of caustic potash evolves 15.96 mgs of oxygen. 15.96 mgs. of oxygen are by the proposition: 1.42908 :-

1,000 : : .01596 : x = 11.168 c. c. of oxygen, or one cubic centimeter of oxygen equals 5.01343 milligrams of caustic potash.

1 c. c. of KOH solution contains 9.689 mgs. KOH.

Experiments.	Reading of Volumeter.	No. c. c. of caustic potash used.	C. c. of Oxygen obtained.	C. c. of Oxygen at 0°C. and 760 mm.	Amt. of KOH found by Nitrometer. Mgs.	Amt. of KOH found by titrating with H_2SO_4. Mgs.	Difference. Mg.
1.	114.90	5.13	11.48	9.99	50.084	49.904	+.180
2.	113.50	10.16	22.36	19.70	98.764	98.440	+.324
3.	110.85	5.01	10.69	9.65	48.389	48.581	—.192
4.	110.40	20.00	42.80	38.767	194.355	193.780	+.575
5.	110.35	14.96	32.00	28.999	145.384	144.947	+.437
6.	110.30	15.02	32.00	29.01	145.439	145.528	—.082
7.	110.20	10.05	21.49	19.50	97.761	97.374	+.387

It will be seen from the above results that the method is quite satisfactory ; the greatest error is, .575 mg., which is $\frac{26}{100}$ of one per cent. too high. The method is quick and accurate, but, as stated by Quincke, large amounts of carbonates cause results to fall too high.

The following experiments were made to ascertain the effects of carbonates upon the results. A solution was prepared containing 0.01 gram of sodium carbonate in one cubic centimeter.

In the first trials one cubic centimeter of this solution was used.

Amount of NaOH, as found by nitrometer=84.2779mgs.
" " " " " " standard sulphuric acid=84.284 "
Difference . . . . . = .0061 "

In the second trial two c. c. of the sodium carbonate solution were used.

Amount of NaOH found by the nitrometer=85.146mgs.
" " " " standard sulphuric acid=84.368 "
Difference . . . . . = .778 "

Trying the same experiments with caustic potash, I found that carbonates had more effect upon it than upon caustic soda.

First trial, using one c. c. of sodium carbonate.

Amt. of KOH found by nitrometer =103.677 mgs.
" " " " " using stand. H_2SO_4=96.793 "
Difference . . . . 6.884 "

Second experiment using two c. c. of sodium carbonate.

Amt. of KOH found by nitrometer =112.501 mgs.
" " " " using standard H_2SO_4=97.568 "
Difference . . . . =14.933 "

From these experiments it will be seen that large quantities of carbonates give high results, and their action on caustic potash is greater than on caustic soda. Minute quantities of carbonates have practically no effect on the results.

The method is quite satisfactory for standardizing caustic potash and caustic soda solutions where only small quantities of carbonates are present.

Ammonia cannot be determined by this method, as it decomposes peroxide of hydrogen in unlimited quantities.

METALS OF GROUP II.

EXPERIMENTS IN THE DETERMINATION OF HYDROXIDES OF METALS OF THE SECOND GROUP.

Calcium hydroxide can be determined by the nitrometer like caustic soda and caustic potash. The gas is given off slowly, but the results are satisfactory.

Peroxide of hydrogen reduces potassium ferricyanide in presence of lime water to potassium calcium ferrocyanide, according to the following reaction:

$$Ca(OH)_2+K_6Fe_2Cy_{12}+H_2O_2=K_6CaFe_2Cy_{12}+2H_2O+O_2.$$

As will be seen from the above reaction, one molecule of calcium hydroxide evolves one molecule of oxygen, or 73.83 parts by weight of calcium hydroxide evolve 31.92 parts by

weight of oxygen. (The atomic weight of calcium being 39.91) 31.92 mgs. of oxygen are by the proportion:— 1.42908 : 1000 : : .03192 : $\times$=22.336 cubic centimeters of oxygen, or 1 cubic centimeter of oxygen=3.3106 milligrams of calcium hydroxide.

1 c. c. $Ca(OH)_2$ contains 1.594 mg. $Ca(OH)_2$.

Experiments.	Reading of Volumeter.	C. c. of $Ca(OH)_2$ used.	C. c. of Oxygen obtained.	C. c. of Oxygen at 0°C and 760 mm.	Amt. of $Ca(OH)_2$ found by Nitrometer. Mgs.	Amt. of $Ca(OH)_2$ found by titration with H_2SO_4. Mgs.	Difference. Mg.
1.	113.20	10.13	5.49	4.85	16.028	16.147	—.119
2.	110.60	10.00	5.39	4.873	16.104	15 04	+.164
3.	110.60	20.00	10.71	9.683	32.056	31.88	+.176

Quinke also determined barium hydroxide by this method and obtained very good results. (Zeit. Anal. Chem. 1892, p. 16.)

METALS OF GROUP III.

According to Davis (Chem. Ind. 1885, No. 6) potassium dichromate may cause decomposition of peroxide of hydrogen in unlimited quantities, the potassium dichromate remaining unchanged. On mixing these substances the red dichromate solution turns brown, gas is evolved with strong effervescence and the color changes again to red.

127.68 milligrams of oxygen are by the proportion: 1.42908 : 1000 : : .12768 : x = 89.344193 c. c. of oxygen, or one cubic centimeter of oxygen equals 2.24589 milligrams of chromic acid. The atomic weight of chromium was taken as 52.45.

For the following experiments, I used a solution of potas-

sium dichromate, which was standardized by titration of an iron solution of known strength using potassium ferricyanide as an indicator. One cc. of the solution contained 3.82985 mgs. of chromic acid.

I placed a known amount of the potassium dichromate with from ten to twenty cubic centimeters of reagent suphuric acid in the outer well of the gas generator and from 5 to 10 c. c. of peroxide hydrogen in the inner.

The generator was inclined to cause the fluids to mix, and allowed to stand five minutes before shaking, so as to give the blue compounds a chance to form.

After waiting a few minutes for this to occur the generator was shaken two or three minutes to drive off the oxygen, and then allowed to stand five minutes. It was then shaken gently to make sure all the oxygen had been given off and placed in the cooling vessel and allowed to come to the temperature of the room.

The volume of oxygen was then read, reduced to 0° and 760 mm. pressure, and multiplied by the factor given above, the result obtained was the amount of chromic acid expressed in milligrams.

1 c. c. of $K_2Cr_2O_7$ solution contains 3.82985 mgs. CrO_3.

Experiments.	Reading of Volumeter.	No. c. c. of $K_2Cr_2O_7$ used.	C. c. of Oxygen obtained.	C. c. of O. at 0°C and 760 m. m.	Amount of CrO_3 found by Nitrometer. Mgs.	Amount of CrO_3 found by titration of Fe solution. Mgs.	Difference. Mg.
1.	111.00	10.06	19.01	17.126	38.473	38.528	—.055
2.	111.30	15.00	28.64	25.73	57.786	57.447	+.339
3.	111.30	15.05	28.64	25.73	57.786	57.677	+ 109
4.	111.30	30.35	57.60	51.752	116.229	116.235	—.006
5.	111.90	4.91	9.23	8.248	18.524	18.804	—.280

The following are the results obtained by shaking the generator *immediately* after mixing the solutions :

1 c. c. $K_2Cr_2O_7$ solution contains 3.82985 mgs. CrO_3.

Experiments.	Reading of Volumeter.	No. c. c. of $K_2Cr_2O_7$ used.	C. c. of Oxygen obtained.	C. c. of O at 0°C 760 m. m.	Amount of CrO_3 found by Nitrometer. Mgs.	Amount of CrO_3 found by titration of Fe solution. Mgs.	Difference. Mg.
1.	115.3	10.06	20 46	17.745	39.853	38.528	+1.325
2.	115.8	20.97	38.40	33.16	74.473	80.311	—5.838
3.	110.8	20.04	37.40	33.75	75.807	76.750	— .943

It will be seen from the above results that unless the generator is allowed to stand a few minutes before shaking that the results are very inaccurate, but if allowed to stand five minutes after the solutions have been mixed before shaking, the gas is given off rapidly and the results are accurate.

DETERMINATION OF THE AVAILABLE OXYGEN IN POTASSIUM PERMANGANATE.

Since peroxide of hydrogen acting on a sulphuric acid solution of potassium permanganate tends to form potassium sulphate, manganese sulphate, water and oxygen, the available oxygen can be determined by adding a definite quantity of potassium permanganate with ten cubic centimeters of reagent sulphuric acid to the outer well of the generator and five cubic centimeters of peroxide of hydrogen to the inner.

On inclining the generator and allowing the fluids to mix, oxygen is given off according to the following reaction :

$$K_2Mn_2O_8 + 3H_2SO_4 + 5H_2O_2 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5(O—O)$$

As will be seen from the above reaction two molecules of potassium permanganate evolve five molecules of oxygen, of which half comes from the peroxide of hydrogen and half from the potassium permanganate ; so one half of the gas volume reduced to 0^0C and 760 m. m. equals the available oxygen in the potassium permanganate.

As it is often desirable to have the potassium permanganate standardized in terms of iron, and as one molecule of potassium permanganate oxidizes ten atoms of ferrous iron, as will be seen from the following reaction,

$$2KMnO_4 + 8H_2SO_4 + 10FeSO_4 = K_2SO_4 + 2MnSO_4 + 5Fe(SO_4)_3 + 8H_2O,$$

by multiplying one-half the gas volume reduced to 0^0C and 760 m. m. pressure by 10.0071, the result obtained is the amount of ferrous iron expressed in milligrams that the potassium permanganate will oxidize.

If we let a represent one-half the gas volume, then $a \times \frac{1.142908}{1000}$ = grams of oxygen.

As two molecules of potassium permanganate oxidize ten atoms of iron, and as five atoms of oxygen contained in two molecules of the permanganate are available, 79.8 parts by weight of oxygen oxidize 558.8 parts by weight of iron ; therefore $558.8 : 79.8 : : x : (a \times \frac{1.42908}{1000}) = 10.0071$ mg. of iron oxidized by permanganate.

For my experiments I used a solution of potassium permanganate standardized by ferrous sulphate, of which I found 1 c. c. to contain .78582 c. c. of available oxygen and to oxydize 7.8639 m. g. of ferrous iron.

I used from five to fifty c. c. of potassium permanganate with from ten to twenty c. c. of dilute H_2SO_4 and five c. c. of peroxide of hydrogen. The acid and permanganate were added to the outer well and the peroxide of hydrogen to the inner. After mixing the fluids the usual precautions were taken. The results are given in the following table :

These are all the results obtained. The gas was given off very rapidly and the results were accurate.

Experiments.	Reading of Volumeter.	C. c of K MnO_4 used.	C. c. of Available oxygen obtained.	C. c. of available oxygen at O° 760 mm.	C. c. of available oxygen found by titration with sol. of $FeSO_4$.	Difference. C. c.	Wt. of iron calculated from nitrometer result. Mgs.	Wt. of Fe. corresponding to $KMnO_4$ solution used. Mgs.	Difference. Mgs.
1.	115.50	19.92	18.00	15.585	15.653	—.068	155.96	156.648	—.688
2.	115.80	9.92	9.035	7.802	7.795	+.007	78.075	78.009	+.066
3.	116.30	15.13	13.77	11.840	11.88	—.040	118.484	118.980	—.496
4.	116.30	49.92	45.60	39.215	39.228	—.013	392.428	392.565	—.137
5.	116.40	29.98	27.40	23.539	23.557	—.018	235.561	235.759	—.198
6.	116.40	5.06	4.625	3.992	3.976	+.016	39.948	39.791	+.157
7.	116.40	24.95	22.82	19.604	19.608	—.004	196.179	196.204	—.025

DISCUSSION.

DR. K. F. STAHL—The nitrometer is a very useful instrument, as far as it goes, but I think it is generally a waste of time to substitute a gas-analytic method for simple titration

which is less liable to error, easier executed and more accurate than gas analytic methods. The apparatus is liable to leak, though, of course, it would not if perfect. In a titration method, using only a burette and pipette, if a drop is lost you can see it. In technical laboratories, whenever possible, I would prefer simple titration, but the nitrometer has very useful applications—in cases where other methods fail.

Prof. F. C. Phillips—It seems to me that the method of analysis with the nitrometer is very nearly parallel with electrolytic methods. It is necessary to know beforehand approximately the amounts of elements in the substance to be analyzed. When you are perfectly sure there is nothing else present than the substance in question, you can go ahead and make the determination. In electrolytic methods you have exactly the same difficulty.

Dr. K. F. Stahl—One trouble I have found with the apparatus in using quicksilver is that it is very hard to keep the rubber tube from splitting. I always put a dish under it, so that in case it does split the quicksilver is caught. Even when using the best rubber tubing, under the pressure it is subjected to, it soon gets brittle and breaks.

Prof. F. C. Phillips—I put one tube inside another when using mercury. The inner mercury tube is then strengthened and protected by the outer tube.

Mr. A. G. McKenna—Can small quantities be measured with the nitrometer more accurately than by titration?

Prof. F. C. Phillips—I do not know that they can be measured more accurately, but any amount can be determined up to a certain limit. Beyond that limit, the oxygen set free would more than fill the nitrometer, and force the liquid into the rubber tube.

Mr. A. G. McKenna—Suppose you had a very small amount of chromic acid, for example, say a milligram, which could scarcely be determined any other way; couldn't you get a perceptible reading with the nitrometer?

Prof. F. C. Phillips—From the data given in Mr. Friend's paper, you can see how much oxygen is produced. He has given very elaborate tables in every case. He says :

"25 c. c. of oxygen under normal conditions were produced by 57 milligrams of chromic acid ;" so that one milligram of chromic acid would represent about half a cubic centimeter of oxygen.

The determination by the nitrometer of so small a quantity of chromic acid as one milligram would probably not be very correct.

After a little general discussion of subjects relating to analytical chemistry, the Society adjourned at 10 P. M.

A. D. Wilkins,
Secretary C. S.

Mr. Gustave Mueller has at length concluded not to publish his paper, read at the May meeting.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

Allegheny, Pa., Sept. 19th, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Carnegie Library Building, Allegheny, Thursday evening, Sept. 19th, 1895, at quarter past eight o'clock, 27 members and visitors being present.

The minutes of the last meeting were read and approved.

The Secretary read the names of two applicants for membership, viz., Arthur M. Bowman and Francis M. Rites. He also read a letter from the American Society of Mechanical Engineers, referring to the accidental death of Mr. E. F. C. Davis, President of the Society.

Dr. Stahl made a report on the expenses of the steamboat excursion on the Monongahela River, showing that there were sold 84 gentlemen's tickets at $3.00 each; 70 ladies' tickets at $1.50 each, making a total receipt of $357. Also expenses for refreshments, $220; for boat, $100; for music, $35.50, leaving a balance on hand of one dollar and fifty cents ($1.50).

It was moved and seconded that the report be received and accepted, and the committee thanked for their efforts in behalf of the Society. Carried.

Mr. Emil Swensson here made the following report:

Report of the Committee on Rooms, showing progress in its efforts to secure quarters in the business portion of the city of Pittsburg, in accordance with resolutions passed at the June meeting, 1895.

Your Committee has found several properties suitable for our purpose, either for rent or for sale, but none for rent with

privilege of purchasing same, as property owners are unwilling to bind themselves to such an agreement for several years in advance. The Society not being in the market for a purchase at this time, your Committee only considered the properties for rent, and have selected two as the most suitable. Property No. 317 Penn avenue can be rented for the sum of $800 a year; but as the same must be altered and repaired considerably to be suitable for our needs, and even then will only give us an assembly room of limited dimensions, and leave us little or no room for sub-letting, your Committee prefer and recommend to the favorable action of the Board of Direction, property No. 410 Penn avenue. This property can be rented for a term of five years at a rental of $1,500 a year, and only needs cleaning, papering and painting for our occupancy. It has a large room, 21x42 feet, on the second floor, in the rear, and will enable us to sub-let two rooms on each of the three floors, in the front, at a possible minimum rental of $900, leaving the rental of the Society as $600, plus fuel and light. Your Committee considers this property an ideal one for our needs, and if rented by this Society an effort should be made to purchase same, and money raised for this purpose, as it is probable that a bona fide offer made at an early date may be considered by the owner. Committee on Rooms,

per Emil Swensson.

Pittsburg, Pa., Sept. 19, 1895.

The President: This report, as I understand it, is simply a report of progress, and requires no special action on the part of this meeting. Any other reports of committees?

The President: At the June meeting of the Association Mr. Leon Le Pontois' paper was held over for discussion at this meeting; we will take that up now. Has anyone anything to say in discussion of that paper?

Mr. Pontois: If I am not mistaken in interpreting the

absence of discussion on the subject as an indication that we all agree as to the best method of converting heat into Electrical Energy, I feel quite gratified.

In connection with this very interesting subject, perhaps I may be allowed to say a few words about the possibility of increasing the efficiency of gas engines driving dynamos, by substituting for the water-jacket generally used for cooling the cylinder, an electro cooling device—some kind of thermopile which would give back to the system, under the form of electrical energy, a part of the heat energy which would be totally wasted otherwise. Truly, in order to be of any advantage, this electro cooling device should be very simple and inexpensive. I believe that both of these requirements might be fulfilled by choosing the couple, iron-antimony.

The products of the combustion might also be caused to heat the thermopile instead of escaping through the exhaust in open air; and thus the working efficiency of the gas engine might be raised from 25 to 27 per cent. This experiment is certainly worth trying.

THE PRESIDENT: Any further discussion on this paper? As nobody seems to be willing to dispute Mr. Pontois' statements, we will pass to the regular paper of the evening, by Mr. John A. McConnell, entitled:

HEAT INSULATION

WITH NOTES ON ASBESTOS.

MR. PRESIDENT AND GENTLEMEN: The great difference between the amount of heat received from the sun by different parts of the earth at different seasons and also the important offices performed by artificial heat, makes, the insulation of heat an important function in the economy of nature and a constantly recurring question in the every-day operations of men.

The earth would be uninhabitable if the envelope of air by which it is surrounded were not a poor conductor of heat. The

earth's surface is a porous formation, thus making it a poor conductor of heat, or, what we call a "good non-conductor," and in this paper I shall use the expression "good non-conductor."

This heat-insulating property of the soil performs an important function by preventing the roots of vegetation from freezing, and protecting everything which is overlaid with a strata of earth.

Under roof, or in any position where it will not become saturated with water, twenty inches of common earth will, in this latitude, entirely prevent the passage of frost. Leaves, grasses and the various kinds of vegetation with which the soil is clothed, being good non-conductors, protect the surface from the heat of summer and cold of winter.

The next important non-conductor liberally furnished by nature is snow, which on account of its light porous character, is a very good non-conductor of heat and forms a kind of supplemental non-conductor outside of the vegetation and soil, being deposited at the time needed and in proportion to the latitude or altitude and consequent lack of heat.

One of the curiosities of heat insulation is the fact that many good non-conductors resemble snow in general appearance, wool and cotton for example.

Among artificial non-conductors (I call these artificial non-conductors because they have to be manipulated before they become good non-conductors) asbestos fibre, mineral wool, pure infusorial earth, lime, magnesia, pure wood pulp, and many others resemble snow in appearance. A white surface radiates less heat than most colors, hence, all other things being equal, white seems the preferable color, at least for the outside surface of a non-conductor of heat.

Having already stated that earth is a fairly good non-conductor and that the vegetation with which it is clothed is still better, we note further that trees and plants themselves are

clothed, the bark of the tree being a very good non-conductor of heat, having just about the necessary degree of porosity and seeming to be designed especially to protect the tree from extremes of temperature. Coming to the highest order of nature we find that land animals are clothed with hair, wool or feathers, the best non-conductors of heat that are known.

Openings in the earth protect the reptile class, while water and ice possess sufficient heat insulating power to protect the fishes, leaving man the only being for whom nature has not provided ready-made heat insulating clothing. It was evidently intended that man should provide heat insulating materials for himself. In supplying his first want, in this line, that of clothing for his person, he at first appropriated the non-conducting clothing of the lower animals, and from a suit of skin with the wool on, to twisting the wool into threads and then weaving it into crude cloth which would keep out the cold, was a very easy step ; then from the spinning of wool to the spinning of vegetables that looked like wool, such as cotton, and thus the making of vegetable fibres into heat insulating cloth was another short step, while the art of making these fibres into felted fabrics, such as hair felt, wool felt and paper, furnishes cheap and convenient materials for heat insulating at low temperatures.

The use of really good heat insulating materials in buildings has been very largely overlooked. In new countries fuel is usually abundant, and hence, under the conditions first prevailing it was easier to furnish fuel to make big fires than to build houses that would confine the heat, and by force of habit this barbarous custom has, to a surprising extent, survived. We to-day build most of our residences with the full knowledge that with the thermometer at zero on the outside, it will be comparatively few minutes until it will be zero in the inside unless we have big fires. I believe it perfectly practicable, and much more economical in the end, to so construct houses that extremes can easily be avoided both winter and summer.

If architects will demand heat insulating bricks for the inner portion of walls and non-conducting plastering and windows, that will largely prevent the passage of heat, they can easily be furnished. Mineral wool filling is very efficient in frame houses.

For preventing water pipes from freezing, for insulating ammonia pipes, etc., in refrigerating plants, and for all similar low temperature work, materials made of animal or vegetable fibres are, except in special cases, more efficient and satisfactory than any mineral substance. They are cheaper, easier to manipulate and being not so easily broken, they are at low temperatures, usually more permanent than mineral coverings.

The insulating of refrigerating plants is becoming important on account of their rapidly increasing numbers and size.

Much of this work presents conditions which are not found in any other class of insulation. The prime object is not to keep in the heat, neither is it to protect from frost. On ammonia pipes and similar surfaces and cold water pipes which pass through warm rooms, the water condensed from the atmosphere is deposited and makes a constant dripping, and the purpose sought is to overcome this. To do this, two things are necessary : First, To exclude the air from the cold surface ; Second, To produce a surface that will not be cold enough to condense wateı from the atmosphere. To accomplish this there must be an air-tight sheathing or jacket and between the air-tight sheathing and the cold body there must be sufficient insulation to keep the surface of the air-tight jacket at nearly the same temperature of the surrounding atmosphere.

Either hair felt or wool felt, with a resinous air-tight sheathing, are efficient for this purpose.

We have referred to clothing because the insulating of boilers, pipes, furnaces, ammonia pipes, etc., with which engineers have to do, is simply to provide for these a species of clothing analogous in many respects to the clothing we wear;

in fact the first attempts at insulating steam pipes, of which we have any record, was by wrapping them with cloth or paper.

We have thus far spoken of insulation at low temperatures, while in insulating boilers, steam pipes, tanks, digestors, heating and puddling furnaces and hot surfaces of all kinds, the problem presented is to produce an efficient and permanent non-conducting clothing for bodies at high temperatures. Insulation at these temperatures becomes imperative as the loss of heat from radiation increases in proportion to the temperature.

According to the experiments and formulæ of *Dulong* in the time that a square foot of surface at blood heat radiates one and one-fourth heat units, at red heat it radiates three hundred heat units, and at white heat four thousand six hundred and four, thus the radiation at red heat is two hundred and forty times, and at white heat three thousand six hundred and eighty-three times as much as at blood heat. As the loss from such surfaces is principally by radiation, and as this radiation takes place in summer as well as in winter, coverings are almost as much needed in summer as in winter, notwithstanding the popular impression to the contrary.

As already hinted, the first attempts at clothing steam heated surfaces were by trying upon them the same kind of materials used in our clothing; it was soon found that when animal or vegetable fibre is applied direct on such surfaces the heat gradually chars and destroys them ; this drove parties both in this country and Europe, to attempt the use of mineral substances only, and many patents were taken out on various applications of clays, lime, etc. These were unsatisfactory, and the next step was the mixing of hair and vegetable substances with these minerals, and a large number of patents were taken out on these combinations.

These were a great improvement, but the fibre burned out, and the need of a fibre that would not burn caused resort to asbestos, and a half hundred or more patents were taken out

in this country on different combinations of asbestos cement alone. The next step was the plan of John Ashcroft, of New York, of forming an air space next to the hot surface; this, while it adds to the permanency of asbestos cement work, is not so good a non-conductor as is generally supposed; one inch of air being to an inch of hair-felt about as thirteen to one hundred. The principle office of air strata or cells is to interrupt the heat waves and as small strata or cells as can be conceived of do this almost as efficiently as a much greater thickness of air.

To Mr. John C. Reed, of this city, now superintendent of the Standard Manufacturing Company, belongs the credit of, in 1875, first originating a practical sectional covering.

The bulk of all that has been written about heat insulating coverings has been in relation to their non-conducting power, and pages upon pages have appeared, especially in the trade papers, endeavoring to show that the coverings made by some particular manufacturer conduct a few units less heat than others; I shall therefore pass this feature briefly, for the reason that it has been sufficiently emphasized, and for the further reason that among a half dozen or more materials most largely used there is no practical difference in insulating power.

Almost all the coverings now being made by reputable manufacturers are good non-conductors, and the question of their relative non-conducting power is not nearly so important as is the question of permanency.

In addition to the reputed tests so largely advertised, experiments have been carried out in the engineering department of a number of our leading colleges, to determine the heat insulating power of different classes of coverings, and the results announced have been very conflicting. Most of the tests have been by condensation, in substantially the same manner as follows—from the main pipe there branches a num-

ber of smaller pipes of the same size and length, each insulated with a different covering; the free end of each pipe is lower than the main, and the water is drained from each and weighed to determine the relative condensation in a specified time, the condensation in the main pipe being drained off separately. A carefully conducted test at the University of Michigan, under the direction of Prof. Cooley, showed in favor of hair-felt, a similar test at our Pennsylvania State College showed mineral wool to be the best non-conductor, and while I have not the report I have been creditably informed that a test at Cornell University showed wool-felt lined with asbestos paper in a favorable light. In some of these tests asbestos coverings have come out ahead, and magnesia in others.

Many of these tests have been conducted by gentlemen of reputation and honor, and were doubtless thoroughly honest. My experiments have shown that different pipes, all insulated with the same material, will at times show, by condensation tests, almost as varied results as the college tests have shown in pipes covered with different materials. More water may be carried from the main with the steam into some pipes than into others, and there are so many things that may modify the result of such tests.

The average results of all these experiments, coupled with my continuous experience in the business these many years, and with twenty-five or thirty different varieties of material, convinces me that coverings can be made either of hair, wool, asbestos, wood-pulp, mineral wool, infusorial earth, carbonate of magnesia, chalk, gypsum, and compounds of these and other materials, that will all be so nearly alike in non-conducting power that a slight change of condition will turn the scale for or against either.

While there is question what particular covering may

save a few heat unites more than some other covering, there is no question about the great difference in loss from a bare boiler as compared with an insulated one.

The experiments of *Peclet* give the following as the conducting power per square foot of four materials, difference of temperature 1° Fahrenheit:

Copper.	515	heat unites per hour.
Iron	233	" " " "
Ordinary stone.	13.68	" " " "
Powdered chalk	.869,	or less than one heat unit.

Hence copper conducts 593 times as much heat as the chalk, iron 268 times as much, and even ordinary stone 15 time as much; hence, why should covering manufacturers quibble so much about a half dozen heat units of difference when the difference between the covering and the iron steam pipe is counted by hundreds of heat units; of course, poor non-conductors must not be used, as their necessary thickness will so increase the radiating surface as to neutralize their non-conducting power. I purposely used chalk in illustration, because it is very similar to the three materials that are being most largely used in combination with asbestos in making high temperature coverings—these are infusorial earth, carbonate of magnesia and gypsum, each dependent for its strength largely upon the asbestos incorporated with it.

Porousness is one of the necessary qualities of good non-conductors, and this porousness necessarily tends to weakness, hence clothing for steam pipes, like the clothing we wear, is liable to wear out. Means for counteracting this natura weakness and for making coverings permanent, is the one thing now needed. I am thoroughly convinced that there is only one practicable way to render coverings really permanent, and that is to strengthen them by reinforcing with iron. Iron can be so incorporated in the body of the covering that the atmosphere cannot reach it; the life of iron thus protected

from the atmosphere is almost unlimited, and thus situated it will hold the covering in place indefinitely, making it really permanent.

I have known this a long while, but I have never been able to introduce it to the public on account of the largely increased cost: when I increase my price enough to justify this improvement other parties get the contracts, but the paying of this additional cost is, in the end, the very best of economy, for coverings thus strengthened with iron will last five or six times as long as any of the coverings now in general use. The iron, being protected as indicated, need not be of sufficient thickness to effect the non-conducting qualities of the covering.

A high degree of permanency is attained by using one-inch thick of any of the well-known mineral coverings, and outside of this from a half-inch to an inch of wool felt paper, made into solid tubes and securely fastened over the mineral coverings.

Felt paper pipe coverings, while excellent non-conductors, have heretofore failed of permanency because they were placed so near the hot pipes that they were gradually burned up. With an inch of good mineral insulation next to the pipe this charring weakness of the felt paper is entirely overcome, and the paper tubes being very strong will, if properly fastened, hold the magnesia, asbestos, or other mineral covering in place two or three times as long as it would otherwise remain.

Less than an inch of mineral under the paper will not protect it, hence this plan means substantially two coverings and adds materially to the cost, and I do not believe it is possible to make heat insulating coverings permanent without making the first cost more than it has heretofore been, but by increasing the cost they *can* be made permanent.

If, gentlemen, I have convinced you that it will pay to increase the first cost and make heat insulating coverings permanent, I will have benefitted all parties concerned.

NOTES ON ASBESTOS.

Asbestos being of first importance in insulating at high temperatures we add the following notes :

The name "asbestos" is Greek, meaning "inconsumable," "unquenchable." Seventeen years ago when I commenced to handle asbestos, the name was unsettled, some writing it "asbestos" and others using the Latin form "asbestus," but the Greek form has now been generally adopted in the English language.

Asbestos is a fibrous mineral; it is the only mineral known that furnishes fibres long enough and strong enough to be woven into strong threads. It is to a high degree fire and acid-proof. These properties adapt it to many useful purposes and it is the *only* material yet discovered that will do for some of these purposes.

Broadly speaking, asbestos is a silicate of magnesia, but in some cases lime displaces the magnesia base; in rare cases alumina takes the place of the magnesia, and what is called "blue" asbestos is a silicate of iron. Iron in this case displacing the magnesia. This blue asbestos or fibrous silicate of iron possesses many times the strength of true asbestos, a thread of it one-twenty-fifth of an inch in diameter carrying one hundred pounds, but by reason of its containing from thirty to forty per cent. of protoxide of iron it is neither fire nor acid-proof; nor is it a good non-conductor of heat, hence does not possess the valuable properties of true asbestos. Silica and water are the only two elements that are always constant in asbestos, the silica rarely falling below forty parts to the hundred, while in some of the anhydrous varieties the water falls as low as two or three parts to the hundred; a good average sample of Canadian asbestos (Chrysotile) showed by an analysis 43 parts silica, 40 parts magnesia, 13 parts water and 4 parts of impurities.

"What variety of asbestos will withstand the greatest

heat?" is a question that is much disputed, almost every mine owner claiming that his product is superior in this respect. My experiments lead me to believe that the anhydrous varieties will resist much higher temperatures than those containing a higher percentage of water. At about white heat the water is driven off; this in the hydrous varieties leaves the fibres in a rigid and easily breakable condition, thus disappointing those who had hoped to use it in small quantities at white heat temperatures.

I say it may thus be destroyed in small quantities, because the fibre is so good a non-conductor of heat that it is extremely difficult to raise any considerable body of it to a white heat all the way through, hence a body of asbestos fibre only a few inches thick may be exposed to a white heat many hours and only destroy the surface next to the fire.

I have stated that the hydrous varieties are injuriously affected by white heat temperatures (I have found it difficult to learn the exact temperature). I wish I were able to state positively that the anhydrous varieties withstand these extreme temperatures, but I cannot. I have not yet been able to experiment with them on large enough scale to satisfy myself in this respect, and the real facts in this particular do not seem to be known by other asbestos manufacturers, or if known have been concealed, for it is the hydrous variety that is almost universally in use.

If it be true that this stiffening is caused by the driving off of the water, then it is reasonable to believe that the loss of the water will have much less effect upon a variety containing three or four per cent. of water than on ordinary asbestos containing from eleven to sixteen per cent.

Most of the asbestos found in the Rocky Mountains contains very low percentage of water, hence I am very hopeful that more extended tests will prove it to be superior in withstanding heat.

Asbestos occurs almost exclusively in contact with serpentine rock; small sample-like deposits of it are found in many places in almost all parts of the world, but its occurrence in commercial quantities is exceedingly rare. The bulk of the entire world's supply being at present mined in the Province of Quebec, Canada, from a little strip of land three or four miles long and perhaps a mile wide, or rather from two small patches, one at either end of the above strip, but it would take millions to buy those two patches. There are a few outside mines in Quebec, two or three of them thirty or forty miles distant from the principal deposits, but the output of these is comparatively small.

The beginning of the development of the Canadian mines was in 1877; prior to that date what asbestos was used was mined principally in Italy, but it was not of great commercial importance until after the discovery of the prolific Canadian mines, notwithstanding that in the form of cloth it seems to have been occasionally used by distinguished persons and for sacred rites all the way back to the times of the Pharaohs.

Small pockets of this mineral have been found along the Allegheny and Cumberland mountains, at different points all the way from Pennsylvania to Georgia; also throughout this same Apalachian mountain range there occurs, and in some places in abundant quantities, a kind of asbestiform hornblend or bastard asbestos.

A great many people unfamiliar with asbestos become greatly excited over deposits of this fibre. I have examined it in almost every state along the line indicated, from Pennsylvania to Alabama, and it is all very similar, being either of a yellowish or grayish color, and usually long, coarse fibre; but all of this fibre is so rotten and lacking in strength that in the present state of the manufacture of asbestos it is not of any value. The only place in the United States where long, white, tenacious asbestos has been found in abundant quantities is in

the Casper Mountains, a spur of the rockies, in Central Wyoming. I have carefully examined all except three or four of the great Canadian mines, and I have seen in Wyoming as abundant deposits as in any of the Canadian mines. The fibre, while very strong, contains less water than the Canadian, hence is less pliable and not so well adapted for spinning. However, as the greater portion of asbestos is used for purposes that do not require spinning, that characteristic would not greatly affect the value of the Rocky Mountain product, and especially if, as seems probable, it withstands greater heat.

There is only, as yet, one railroad near the Wyoming deposit, and this lack of competition makes the long haul expensive, but it is also a long haul from Quebec to the most parts of the United States.

There is a duty of 25 per cent. on all except crude and ground asbestos and pyper stock, and if the tariff laws were enforced the people of the United States could be supplied in the main from Wyoming, and thus give asbestos the benefit of the policy of our Government in protecting American industries; but at present all kinds of manufactured asbestos fibre are being imported from Canada, free of duty, under the classification of ground asbestos and paper stock. The provision for admitting ground asbestos and paper stock free was only intended to apply to these, hence the present abuse of our tariff laws by which fibreized asbestos is admitted free defrauds the Government and discourages the production of asbestos in the United States.

The blue or silicate of iron asbestos is found in abundance along the great Orange river in South Africa, and in smaller quantities in Greenland and Norway; specimens were exhibited at the World's Fair.

Detached fragments of asbestos of various and peculiar formations occur, in some places numerously; these are known as Mountain Wool, Mountain Cork, Mountain Leather, Mountain Paper, etc., owing to their resemblance to these materials.

What is known as flossy asbestos, with fibres often a foot or more long, is found in Italy in either horizontal or dipping veins; but nearly all the asbestos produced is from mines having fissure veins; these fissures being vertical or at slight angles, and the fibre of the asbestos running across the fissure.

The veins of asbestos filling these fissures are from three inches wide down to the thickness of heavy paper, and when their edges are exposed in the mines these very small veins look like white threads running up and down through the rock. Many of the veins run to the surface, and look like strips of weather-stained white ribbon running over the surface of the rocky ground; they extend to the depth of several hundred feet in the earth.

These fissure veins are sometimes in groups, only a few inches apart, sometimes they are several feet.

The mining is done, if on a mountainside, by blasting down the whole face of the rock, in which the vertical veins are imbedded.

The breaking up of the rock to remove the seams of asbestos makes the whole operation much like quarrying common broken stone; if the ground is comparatively level, a shaft is first sunk, and then the sides blasted down and the rock removed, the process being continued until sometimes the shaft is widened into an acre or two of area.

When I was last at the Canadian mines, four years since, I was told that one shaft was down two hundred feet. I have been informed that since then it has been made deeper, with no signs of decrease in the size, number and quality of the veins; indeed, it is claimed that it improves in every respect as the mines become deeper.

This is not always true, and while I am not very familiar with the mining, it is my opinion that the improvement with depth is not so great as is generally believed. The deepest

shaft in Wyoming is only about fifty feet, and that far shows the character and constance of the veins to be much the same as in Canada.

Veins have been found in this Wyoming mountain seventeen or eighteen hundred feet below the other mines, but the veins may not extend this deep, as this may have slid down from the top.

As this paper is already too long, I cannot cite the various theories regarding the processes of formation of this peculiar and interesting mineral; suffice it to say that while differing in details, most of the theories believe it to be produced by crystalization under combined igneous and aqueous agencies, each fibre being an elongated crystal or else a series of minute crystals attached. Prof. Dana, in treating of crystalization, says, "When a solution is spread thinly over a large surface minute crystaline points encrust the whole, and if the solution be gradually supplied as crystalization goes on, it is obvious that the minute points may elongate into crowded prisms of fibres, producing a fibrous structure; such a structure is common in narrow seams in rocks and the fibres are usually elongated across the seam."

DISCUSSION.

THE PRESIDENT: Has anyone anything to say on this very interesting paper? This is too interesting a paper to let go by without some discussion.

MR. PONTOIS: I should like to signal a very interesting application of the fire-proof quality of asbestos to the insulation of high tension wires, made by a Pittsburger, whose name is not present to my memory. A bare copper wire a few inches in length is carefully wrapped with asbestos, and then pressed in the center of a block of molton glass—the asbestos forms a fire-proof cushion, allowing the wire to expand or contract without breaking the glass insulation—and in

a certain measure prevents the glass from cracking if the wire is accidentally brought by the current to a high temperature.

MR. R. L. WALKER here stated that if the members would call at Phillips' store on Sixth street they could see the glass, covered with asbestos, mentioned by Mr. Pontois.

MR. C. HYDE asked Mr. McConnell what he considered the best method of testing, to which he replied he deemed the plan of inserting a thermometer, and then surrounding it all with an insulated box so as to confine the heat as more satisfactory than the condensing test for reasons already given.

MR. EMIL SWENSSON: In this connection it may be of interest to our members to give a brief description of the heat insulating covering of the large steam pipe line, which carries the steam supply of the Keystone Bridge Works from the Lucy Furnaces across the furnace stock yards and the A. V. R. R. tracks to and over the buildings of the bridge works. This line is composed of about 600 feet of 14-inch pipe and about 300 feet of 10-inch pipe and is exposed to wind and weather in its entire length, being carried about 30 feet above the stock yard floor, about 24 feet above the railroad tracks and about 22 feet above the floor level in Keystone Bridge Works. On account of the great height at which it had to be carried, it was decided to support the pipe from below, rather than to hang it up as is usually done, but how to do it and at the same time take care of the expansion and not interfere with or break the necessary heat insulating covering now became a serious problem. To permit a free expansion movement it was decided to support the pipe in cast iron shoes resting on roller nests. But of course the shoes could not come in direct contact with the pipe without breaking the covering. The insulating materials being of a very porous nature, and consequently having small resistance to crushing, an experiment was made to test the strength of asbestos cement and its various modes of application, suitable on this line. A five foot long section of the 14-

inch pipe was covered in three different manners, first similarly to the proposed covering for the entire pipe line, consisting of an air-space of one and a half inches, having five tin thimbles or studs to the square foot, holding a heavy wire netting away from the pipe; over the top of this was applied two inches thick asbestos cement in four coats. The second kind was the same as the first except that wrought iron gas pipe was used instead of tin for the thimbles at the saddle rest for a space of about 15x 18 inches. The third kind was similar to the first except that the air-space for a width of 15 inches all around the pipe was filled in solidly with wired on asbestos cement. A saddle or shoe 12 inches square was placed on the various kinds of covering and loaded until the cement began crushing in. I do not now remember the different loads used on the first two kinds, but I do remember that the first ones were both too weak, the first one being the weakest. The third showed ample strength for our purpose, carrying a load of 3,200 lbs. without showing sign of crushing. As the load to be carried was about 1,000 lbs., and as the size of the shoe would be about 15x18 inches, the safety factor would be ample, especially after hardening of the cement. This last described method of construction was consequently decided upon as the one to be used at the saddles.

After the asbestos cement had been put on it was covered with canvas, sewed all around the pipe, then painted with white lead, and finally the upper two-thirds of the pipe was covered with No. 24 guage sheet iron, wired on and painted with oxide of iron. The covering has now been on for three years and is in as good condition as when first put on. Its value as a heat insulator is best illustrated by the fact that when the uncovered pipe will burn the hand, the heat can barely be detected on the outside of the covering.

Mr. McConnell: I am gratified to hear Mr. Swensson make so favorable a report on that work, as at the time I expressed some doubts to him and also to Superintendent Brown.

It was somewhat a new departure, being perhaps the only large pipe in the world supported only outside of the asbestos covering; and we will all, I guess, in our own business, fall into ruts, and I really feared that we could not support that great weight on the outer surface of the asbestos covering without crushing into the cover, and I feared that the expansion or contraction of the pipe would injure the asbestos covering at the supporting saddles, as there were some 3,000 pounds weight to the square foot, I think something like that, and the pipe was very long, the larger one extending from the Lucy Furnaces, across the Allegheny Valley Railroad, up through the yards, to the Keystone Bridge Works, making a good many hundred feet; I do not know how many. I thought I would get up to see that before I finished my paper. That is only one of a great many contracts having special difficulties that I have put up in the last 17 years. I did not mention details in my paper for fear of making it too long.

THE PRESIDENT: If there is no further discussion, a motion to adjourn will be in order.

Moved and seconded that we adjourn. Carried.

DANIEL CARHART,

Secretary.

MEETING OF THE CHEMICAL SECTION.

Sept. 20, 1895.

The following paper was read by Mr. A. G. McKenna, of Duquesne, Pa:

AN IMPROVEMENT IN THE ZINC REDUCTOR FOR THE DETERMINATION OF IRON OR PHOSPHORUS.

In using the ordinary form of reductor, for reducing solutions of iron or molybdic acid by passing through a column of finely granulated zinc, an enormous amount of zinc is consumed in the useless reaction between the free acids necessarily present and the zinc; while a comparatively small amount takes part in the reaction by which the iron or molybdic acid is reduced.

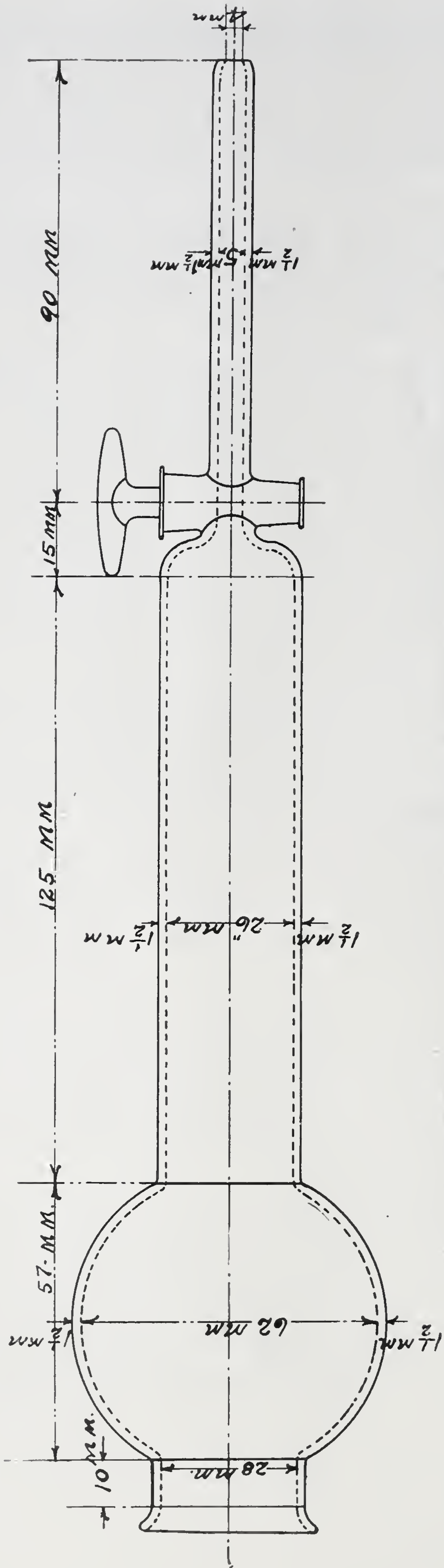
The reactions spoken of are $Fe_2(SO_4)_3+Zn=2FeSO_4+ZnSO_4$ and $H_2SO_4+2Zn=ZnSO_4+H_2$.

The great volume of hydrogen set free by the second reaction proves very annoying during the operation of reduction, and unless an extremely powerful suction is used the liquid can scarcely be drawn through the zinc.

As it is known that zinc which has been amalgamated is scarcely attacked by weak acid, it occurred to the writer to try the effect of amalgamating the granulated zinc before using it in the reductor.

The results were most satisfactory. The reaction between the zinc and free acid was almost entirely suppressed, there being scarcely any evolution of hydrogen during the passing of the solution through the zinc, while the speed of the reduction was not in the least diminished.

The form of apparatus used is shown in the accompanying sketch. In preparing it for use a small plug of asbestos is placed in the bottom of tube just above the stop-cock: a very thin layer of asbestos will be found sufficient. It should be packed loosely so that a steady stream of water will run through



GLASS SKETCH OF REDUCTION TUBE FOR LABORATORY.

CLASS XI., No. 253.

Duquesne Steel Works,

The Carnegie Steel Co., lim'td.

without suction. On this plug about two hundred grams of granulated zinc is placed; (the zinc should be of such fineness that it will pass through a twenty mesh sieve but not through a thirty mesh) before placing it in the reductor it is thoroughly amalgamated by stirring up with it, in a small beaker, about five grams of mercury and twenty-five cubic centimeters of a five per cent. solution of sulphuric acid. The zinc fills the straight part of the tube about two-thirds, leaving a sufficient space to allow the addition of the solution which is to be reduced. After the zinc is in position the tube is inserted in a filtration flask by means of a rubber stopper and the flask connected with the suction; the zinc is washed several times with a five per cent. solution of sulphuric acid and is then ready for use.

For the determination of iron in ores, the solution of the ore after the excess of free hydrochloric acid has been driven off, is diluted and filtered into a five hundred cubic centimeter graduated flask and diluted to the mark with water after cooling. By means of a one hundred cubic centimeter pipette, one hundred cubic centimeters is transferred to a small beaker; five cubic centimeters of a fifty per cent. solution of sulphuric acid is added and the contents of the beaker are poured into the reduction tube; the glass stop-cock being opened sufficiently to allow the solution to be drawn through by a gentle suction. There will be scarcely any evolution of gas, and the reduction will be complete even though the solution runs through in a steady stream. The tube is now washed four times with a five per cent. solution of sulphuric acid, using in each washing about fifty cubic centimeters of solution. It is important during the washing to avoid drawing excessive amounts of air through the zinc, as for reasons stated below, this will lead to low results. The reduced solution is now titrated by standardized permaganate and a duplicate determination made on another one hundred cubic centimeters taken from the graduated flask. These duplicates should âgree within one-tenth per cent.

In some of the first experiments it was found that a blank made by washing five successive portions of five per cent. sulphuric acid through the tube, allowing a current of air to be drawn through for a half-minute between the washings, required an amount of permanganate equivalent to .003 grams of iron although no iron could be found in the solution. Blanks made in a similar way except that no air was drawn through the tube, were colored by the first drop of permanganate. Duplicate determinations of iron, allowing in one case air to be drawn through and in the other not, invariably gave results from two-tenths to three-tenths low, in the cases in which air was drawn through alternately with the sulphuric acid. The facts evidently point to the formation of some compound which oxidized iron and was itself oxidized by permanganate. A test for hydrogen peroxide was made in one of the blanks by adding a few crystals of potassium iodide; on standing a few minutes the solution began to show the characteristic color of free iodine. On titration with hyposulphite it was found that .0009 grams hydrogen peroxide was present in the blank. This amount of hydrogen peroxide would be sufficient to oxidize about three milligrams of iron. In regard to the amount of zinc consumed in the reduction of a gram of sixty-three per cent ore, a determination of the zinc in the solution after complete reduction, gave six-tenth grams of zinc.

NOTE. The discussion of this paper will be taken up at the October meeting.

The Secretary.

Engineers' Society of Western Pennsylvania.

Allegheny, Pa., Oct. 17th, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, October 17th, 1895.

The meeting was called to order at 8.30; Mr. W. G. Wilkins, the Vice-President, in the chair, and 28 members and visitors present.

The Minutes of the last meeting were read and approved.

Messrs. Arthur M. Bowman and Francis M. Rites, applicants for membership, were by ballot unanimously elected members of the Society.

Mr. Charles Hyde then read his paper entitled :

NOTES ON A TRIP THROUGH RUSSIA.

In the fall of 1894 I had occasion to visit Russia—that mysterious land where both the civilization and barbarism of Asia and Europe meet and mingle, and where the manners, customs and superstitions of the Dark Ages survive side by side with the scientific achievements, the enlightenment and the skepticism of the end of the nineteenth century.

The visit was a professional one, undertaken in the interest of leading business men of this and Eastern cities, with a view to the establishment of manufacturing industries in Russia, on a large scale on American lines, and with American capital, and it was desirable to know first what the facilities and what the competition would probably be. It occurred to me that a brief account of the trip, of the works visited, and some comments on the present state of the iron and steel in-

dustry in Russia, might prove of interest to this Society. At the same time, in a country so little known to the outside world as Russia, there is much to attract the attention of one visiting it for the first time, as regards the social, religious, and domestic life of the people, as well as on the side of their manufacturing and commercial life.

At the risk, therefore, of stating facts and describing scenes which, though novel to me, would be thoroughly familiar to a student of Russian history, or Russian manners, as portrayed in their literature, I shall make this paper, if you will allow me, a general description of a trip to Russia, places visited and impressions received, rather than a paper devoted exclusively to engineering and manufacturing, such as, I cannot but feel, would be more appropriate to read before a society of this kind.

Leaving New York on Saturday, the 8th of Sept., by the Lucania, and favored by fair weather during the whole passage, we made a record trip of 5 days, 8 hours and 40 minutes to Queenstown, which record I believe still stands, and which most curiously was the exact time to the minute of the Lucania on the outward voyage to New York, thus making a record each way of exactly the same time on two consecutive trips.

Reaching Liverpool, as we did on Friday afternoon of the following week, we could have arrived in London in time for the night train running in conjunction with the boats for Ostend, Flushing or Calais, which are timed to connect with the Berlin and St. Petersburg express, so that it would have been possible on that occasion to reach St. Petersburg in less than nine days after leaving New York, a distance of nearly 5,000 miles, extending at that latitude nearly one-third round the world.

As a matter of fact we spent two days in England and one in Berlin, reaching St. Petersburg on the morning of Sept. 20th, or in less than 12 days from New York. It is indispensable to any one wishing to enter Russia to have one's

passport properly filled out by one's own State authorities, and this passport must be visee by a Russian consul before reaching the frontier. Incidentally I may mention that with improperly endorsed passports it is just as difficult and sometimes much more urgent to get out again.

There is, however, no difficulty in obtaining passports, as a rule, except in the case of Hebrews and Roman Catholic priests, both of whom require a special permit from the Russian government before being allowed to enter Russia.

At the station at which we crossed the frontier from Germany to Russia, called Eydkunnen on the German side, and Virballen on the Russian side of the line, the gauge of the railroad changes from the standard gauge of 4 feet 8½ inches, which prevails throughout Holland and Germany, to 5 feet, the standard gauge of the Russian roads. As this railroad is regarded as a means for the transportation of troops, rather than passengers or merchandise, this change of gauge is intended to prevent any sudden invasion from either side, the inconvenience of the change as regards the commercial use of the railways being completely ignored, the military character of this railroad in particular being still further emphasized by the fact that it runs in almost a straight line from the frontier station of Virballen to St. Petersburg, except where necessary to connect with a fortress or military station, whilst important trading towns on the Baltic Sea and Gulf of Finland are reached only by branches or not at all.

The Russian cars of the first class are commodious and comfortable, being constructed on the same plan as those largely used in Germany, viz., with a corridor running along one side, and private rooms connecting with this corridor running across the car. The extreme width of the car being 10 feet, allows for a corridor of about 2 feet 6 inches wide, and a room 7 feet long, inside measurement. I may mention that on most of the roads there are four classes, so that one has plenty of choice as regards accomodation.

The Northern railroads use wood for the most part, as fuel, which, though plentiful and clean, has the drawback inherent to a fuel of low Calorific value, that the power developed is small in proportion to the weight consumed, and, consequently, the speed of the trains is slow, averaging about 25 miles, only, per hour. The stoppages made, too, are rather frequent, and to one anxious to get through, appear inordinately long, but, as the trains do not carry dining or buffet cars, a stop of from 30 to 45 minutes about meal times is appreciated, especially as the buffet arrangements at the stations are first-rate. Feathered game was plentiful at the time of our visit, and the Russian caterer had, as a rule, a very pretty taste in dressing, cooking and serving it. In the most out-of-the-way corners of Russia, on the railroads and on the river boats, one can almost invarably depend on getting good food, well cooked and at a reasonable price, which was certainly opposed to my preconceived notions on matters gastronomic in Russia; whilst as for wine, most of the well-known brands of claret, Rhenish wine and champagne are obtainable, together with a number of native wines, principally from the Crimea. Warnings as to the bad effect upon travelers of drinking the city water are conspicuously posted on the door of every room in the St. Petersburg hotels, and no particular effort, as far as we could learn, was being made by the authorities to remedy this distressing state of affairs, especially as the supply of native wine appeared to be holding out fairly well, and no one seemed to be taking any unnecessary risks with the water.

The site of St. Petersburg, as you all know, was chosen by Peter the Great, partly on account of its inaccessibility to a foreign foe, at any rate by land, as it is surrounded in every direction by wide marshy plains and dense forests for many miles, the whole country round being but a few feet above the sea level. It is essentially an artificial city, just as Washington is, existing simply as the seat of the government and built largely to order, and not by natural growth. Much judgment

and foresight are shown in many of the public works, as for instance in the canal system, the massive and substantial embankments along the Neva, and the open spaces and squares surrounding many of the government buildings, which open spaces, being well wooded, afford pleasant breathing spots for the populace in summer.

The river Neva being the outlet of Lake Ladoga, the largest body of fresh water in Europe, is kept constantly full, runs with a strong current, and is capable of floating the heaviest iron-clads. For nearly six months in the year, however, navigation is suspended on account of the ice, the pontoon bridges, of which there are several, are drawn ashore, and the river becomes the main highway of the city, for vehicular traffic of every description, just as in summer it is covered with launches, ferry-boats and barges.

Although situated as far North as Southern Greenland and further North than Labrador, it is in winter that the St. Petersburg season is at its height, the landed proprietors of the Crimea and of the midland steppes, from Poland and from the Volga Valley, flocking to spend the winter, and especially Christmas, which, by the way, is kept twelve days later than by Western nations, in the gay capital of the frozen North. The Russian still clings to the old style of calendar, and consequently continues to get further and further away, with the lapse of centuries, from the actual season, it being only a question of time before the 21st of December will be the longest day, unless a more rational system is adopted. Of course, educated Russians, who are as a rule polished gentlemen, good linguists, and courteous and punctilious to a degree, understand this perfectly well, but several of them, questioned concerning this matter, gave as a reason for continuing the present system the opposition of the church and the peasantry to any change, largely because every day is assigned to some saint, some days being divided up amongst several, and they fear that the particular saint or saints whose day was dropped

would feel defrauded and be apt to resent the insult. When it is considered, too, that every Russian, male and female, is named after some saint, and keeps the anniversary of the saint's day with the same or more ceremony than they keep their own birthday, there would be some hundreds of thousands who would feel that not only had their patron saint been insulted, but their own eternal welfare had been put in peril.

The power of the Czar over the people is largely owing to the fact of his being the head of the Church, and he would hesitate to sanction any scheme which might tend to excite the opposition of a superstitious and ignorant peasantry, and the not much less superstitious, but powerful and wealthy priesthood, so that the change, though recognized as desirable, is not likely to take place for some time to come. The strong religious feeling of the Russian is very much in evidence in the northern and central portions of the empire, at least as far as outward observances are concerned, being manifested in the streets by raising the hat and elaborately crossing themselves in passing a church, or a shrine (which usually resembles a gaudily colored Kiosk) containing a picture of some saint, and it is impossible to go very far in St. Petersburg without passing one or the other. The ceremony is not confined, by any means, to pedestrians, as the occupants of a street car reverently go through the form as the car passes along the streets, and the driver of your "droschky" which answers to the western cab, will dexterously hold his hat, whip and ribbons in one hand, and calmly cross himself with the other without checking his horse.

Many of the saint's days, too, are observed by closing the stores and sometimes the works, so that it is always advisable in making arrangements ahead, for visiting works, picture galleries, or stores, to make careful inquiries beforehand. It is also the custom, which seemed curious, and just a little ridiculous, to have a shrine in each department of a works—the Bessemer, Open Hearth, Rail Mill, Hammer-Shop, Machine

Shop, etc., each having its shrine to its patron saint, right in the midst of the smoke and dust of the mill, and no plant can be operated unless these shrines are provided, at least in St. Petersburg. The government also insists upon the operators of a plant providing baths, hospitals and dwellings for their employes unless the works are situated in a large city, when the latter requirements may be dispensed with.

Although the neighborhood of St. Petersburg has very few natural advantages as a manufacturing center, there are a number of important industries carried on there, principally in the hands of the government or engaged in work for the government. Amongst the former there are the government glass and china factories ; a large plant for the manufacture of playing-cards, of which the government has a monopoly, and the ship building yards, from which the largest iron clad in the Russian navy was launched during our stay. Amongst private concerns engaged in government work there are the Poutilof, Neviski, Alexandrovsky and others. The first three are steel works and each of them was visited.

At the largest of these, the Poutilof works, they employ about 7,000 men, have a Bessemer and Open Hearth department, and manufacture rails, plates, beams, angles, channels, axles, tyres, bars and general merchant iron. In addition to this they build locomotives, torpedo boats, gun carriages, bridges and buildings, and also have a special department for the manufacture of projectiles, which department no visitor is allowed to see. Some of the product, however, was exhibited, amongst other things a solid shot which had passed through an armour plate, the point of the shot being practically as good as when fired.

The whole of their raw material is imported principally from England, and a six months' supply of pig, coke and coal must be stocked before the winter sets in. The duty on everything is high, which, together with freight, makes coal cost

from $4.40 to $5 per ton, and coke $6.80 to $7.50 per ton, and pig iron $27 to $28 per ton.

The Bessemer department contains two four-ton vessels, three iron-melting cupolas and one spiegel cupola. The spiegel is tapped directly into the pouring ladle, and not into the vessel; hydraulic pressure used for cranes, tilting, etc., is about 300 pounds per square inch. The open hearth department contains 12-10 ton furnaces in a straight line, having a casting pit extending the full length, the ladles being carried on trucks extending across the pit, and running on rails laid on either side. The moulds and ingots in this department are handled by traveling steam jib cranes, which seem to answer the requirements very well. Ingots for rails are bloomed down on a reversing mill in 10 passes to an 8-inch bloom, which is transferred on a buggy to a 3 high rail mill, and finished in 11 more passes. The capacity of this mill is about 200 tons per day, all the work of drawing and charging the furnaces, transferring and manipulating being done by hand. Labor saving appliances are but little used in any of the Russian mills, especially in St. Petersburg, as labor is cheap, in spite of the high tariff on everything, common labor being paid about 40 cents a day and skilled labor from $1 to $1.50.

The finished product of both the rail and structural mills looked first class, in fact it must be good to pass the very rigid government inspection, whilst the steel castings which they were making to take the place of forgings in gun carriages and locomotive construction, equaled anything of the kind I ever saw.

The plate mill department is rather old-fashioned, having been built fifteen or twenty years ago, the widest plate they could roll would be about 80 inches, I should judge, and in this department, as elsewhere, the number of men employed appeared excessive for the amount of material turned out, as compared with our modern mills.

In the locomotive shops a great deal of new machinery

had been recently added, and the general equipment was fairly good, but too crowded. Over-head cranes, some operated by steam, some by ropes and some by electricity, handled the material in the smith, machine, hammer or erecting shop, as the case may be, and the flanging and riveting work on the locomotives turned out was first-class in every respect. The government inspection was not only rigid, but absurdly arbitrary, in some respects, though anyone who has had much to do with government work knows perfectly well that unreasonable requirements and arbitrary inspection is not confined by any means to Russia.

The compound type of locomotive seems to be coming into very general favor, there being several different arrangements in use, though the favorite type appeared to be with the high pressure on one side and low on the other.

In the St. Petersburg mills, for the most part, the mill engines are of the non-automatic type, whilst as to boilers, I noticed in the Poutilof works, alone, boilers of the modified Babcock & Wilcox, the Lancashire, Cornish, horizontal tubular locomotive and plain cylinder type, many of these boilers being fired by the waste heat from heating furnaces.

At the "Nevski," another large works on the Neva, above St. Petersburg there are two open hearth furnaces of the acid type, as are all those at the Poutilof, and here also they build torpedo boats and locomotives. As illustrating the extreme rigidity of the government inspection I was informed that out of 200 plates submitted to the inspectors for the artillery department only 24 were accepted, the rest being rejected principally on tensile strength and ductility test. Sixty plates were ordered from the Belgian firm of Cockrill & Co. in order to complete their contract, and out of these sixty, 48 were rejected.

At the Alexandrovsky works, the principal output of which consists of plates and structural material, they have seven open hearth furnaces, of which six are operated by the basic process. The metal is tapped directly from the furnace into the molds,

they being set on a revolving table in a small circular pit and brought alternately under a fixed funnel.

The object of this arrangement was, presumably, to save expense for pits, cranes and ladles. What the effect would be if the furnace broke out, as furnaces sometimes will, can be readily imagined by anyone familiar with open-hearth practice. It is bad enough where you have a clear pit and good crane capacity, without having a lot of mechanism in the pit, and cranes capable, only, of handling molds and ingots, to depend upon.

For rolling their plates they have a reversing mill, operated by a three cylinder engine, and all the plates are passed through straightening rolls as they come from the mill. The result is a very fine looking plate of smooth surface and free from buckles. Very little handling is done here by mechanical means, as many as 17 men being required to draw a 5,000 pound ingot from the heating furnace and take it to the rolls.

At Moscow, at the Gougon works, the arrangement of the open hearth plants struck me much more favorably than did that of the St. Petersburg works, though, of course, the latter plants were older. At the Gougon works the furnaces, two in number, were of about 30 ton capacity each, with plenty of room both on the side of the charging floor and on the pit side, which was also properly equipped with hydraulic cranes. Crude petroleum from the Caspian Sea, brought up the Volga and Oka rivers in bulk, in covered barges, is largely used for fuel at these works both for heating and boiler purposes, but it is not used in the open hearth furnaces, nor did the method of using it seem the most economical. At the end of the furnace, and on the outside, the oil is allowed to fall in drops into a shallow iron trough, where it is ignited and is drawn by natural draught into the furnace. At these works, too, they have recently put in some compound automatic engines built in England ; have a good modern mill, and well equipped nail, spike and wire factory. For this class of work they can compete successfully

with other districts, but for heavy products they are handicapped on account of the high freights on all raw material. For fuel they are dependent upon coal and coke from England or Germany, or oil from the Caspian, a distance of some 1,500 miles, whilst much of their pig iron is either imported or comes from the Urals, a distance of a thousand miles.

As regards oil, too, all this distance is against the stream, and the Ural pig must come against the stream for at least half the distance, and I know, from personal experience, what pulling against the stream in the Volga means. During half the year, too, the rivers are not navigable on account of the ice.

Although there is an abundant supply of rich ore in the Ural mountains, it is impossible to smelt it in large quantities there, owing to the absence of any fuel except charcoal; the government restrictions as to the quantity of timber felled in any district per annum, and other requirements as to smelting, rendering it difficult to produce iron in large quantities in this region, though the finest ores in Russia, and possibly equal to anything in the world, are found here. There is a fortune in it for any one who can devise a practical means of smelting Ural ore with crude petroleum, as the ore can be floated down to any point on the Volga to meet the oil from the Caspian.

Several schemes have been proposed, amongst others to soak coke in petroleum, and use the standard coke, which might possibly be of use if you could keep the oil from volatilizing long enough to be of any use in reducing the ore. Others claim to be able to reduce the ore by means of the oil, without the use of coke at all, but the schemes referred to me did not seem to hold out much hope of success.

Most of you, however, know more about blast furnace operation and the use of oil than I do, and it would be interesting to know what the possibilities and limitations in this direction are.

The coming district in Russia for the manufacture of steel

on a large scale, is undoubtedly in the south, as that is the only district where coking coal is found in large quantities of a good grade, and here, too, there are some good hematite iron mines, notably at Krivoi-Rog.

The most successful plant in this neighborhood, and possibly in Russia, is the "New Russia Iron Works," founded by a Mr. Hughes, an Englishman, in the early seventies, and recently converted into a joint stock company, with offices in London.

Situated on the Donetz coal field, they raise the coal right in their works yard, and have some hundreds of Coppee coke ovens, starting from the pit-mouth, and extending down to the blast furnaces so that no unnecessary expense is incurred for rehandling.

Their blast furnaces are of modern design, are well equipped with hot blast stoves and independent blowing engines, and are capable of turning out about 200 tons of pig per day each.

At present all the steel for rails, which is their principal product, is made by the open hearth, acid process, but the metal is charged in a molten state from the blast furnaces. Their main reason for building an open hearth instead of a Bessemer plant, was because, at that time, all the railroads in Russia were using iron rails and they proposed to melt old rails and convert them into steel, which promised to be a remunerative business, until, during the American boom of 1881, the price of iron rails rose to such a figure that the whole country was scoured for them, they being sold in large quantities, and imported steel rails put down in their place.

The Hughes Company are now, however, erecting a Bessemer plant and rail-mill on modern lines, which will greatly increase their capacity and reduce the cost of manufacture.

At Sulina, on the extreme eastern edge of the Donetz coal field, and where the coal is a friable anthracite, the "Postuchoff" works are operating two blast furnaces with anthracite for fuel—

the only two so operated in Russia—and the remainder of their plant is fired by the raw anthracite, or by gas prepared from the more friable and gaseous portions. At this point they obtain on the property on which the works stand—limestone, building stone, silica-sand, iron-ore and coal, so that the location would seem to be an ideal one for a steel works, which would be the case if the iron ores were richer in iron, and contained less phosphorus, and the coal were coking coal and contained less sulphur. They were about to erect two open hearth furnaces here, one acid, one basic, using chrome ore from the Caucasus for lining the latter furnace.

In connection with this plant, where we were treated in the most hospitable manner—which, to be perfectly fair, was the case in connection with practically every works in Russia which we visited, the manager was anxious to have some particulars of the working of blast furnaces, on anthracite, in the United States, as regards the dimensions, output, consumption or fuel per ton of pig produced, pressure of blast, etc., which particulars some of the members of this society can no doubt supply.

Speaking generally of the steel and iron industry in Russia, it is more advanced than is generally supposed by outsiders, and though many of the mills are a little out of date, they were well up with the times when they were built, and with the recent revival of business there, and the encouragement given by the government to open up new districts by the building of railroads, the manufacturers are taking advantage of the opportunity to remodel their plants on the most modern lines. The locomotive works of the Struvee Company at Kolomna are being equipped throughout with electric over-head cranes, hydraulic riveters, multiple drills, etc., and in the case of large tools, each one is driven by an independent motor. The Siemens-Halske Company have a large and successful plant in St. Petersburg, from which they ship motors and general electrical appliances all over Russia, and at the same time give

object lessons, by the way in which their own shops are operated, as to the best and cheapest methods of running machine shops and similar establishments.

One of the oldest steel works in Russia is the Sormovo works at Nijni-Novgorod, where, besides making plates, tyres and axles, and general merchant iron, they also manufacture a great many freight and passenger cars, and build compound engines for the vessels plying on the Volga. We traveled all night from Moscow to see these works, only to find them standing on account of its being a saint's day.

The town of Nijni-Novgorod is most widely known, of course, as the site of the great Fair which takes place in August each year, and which attracts traders and merchants from further Asia, India, Persia, the Caucasus and the steppes of Kurdistan, many of whom travel for months, to meet representatives of Russian, English, German, French and American manufacturers, and exchange their tea and silk, their carpets and rugs, etc., representing the accumulated labor of a year, for the iron and cotton goods, guns and ammunition, cutlery, etc., of the Western nations.

It is said that as many as 750,000 people annually visit this fair, either for trading or as sight-seers, and it can readily be imagined that many millions of dollars worth of merchandise change hands. The fair was over for the year when we reached Nihjni, and the one section, the larger of the city, was absolutely dead, street after street of houses (mostly of wood), with hotels, churches, theaters, and everything that goes to make a city, closed until the following August. The construction of the Siberian railroad, will soon reduce the importance of the Fair, if not kill it altogether, as the necessity of its existence will cease as soon as communication with the people interested becomes rapid and regular.

The most picturesque city of Russia and the most typically Russian, is undoubtedly Moscow, which has been besieged, captured, burned, or otherwise destroyed, about a dozen times

in its history, and yet retains its irregular and old world-look, with its outer walls and inner walls, Kremlin and massive gates dating back to Tartar times. Some of the churches are decidedly striking in appearance from their design and architecture, all of them from the amount of gilding and coloring on their domes and minarets, making bright and attractive objects, especially when the city is seen from a little distance. Most of the houses are roofed with sheets, which, being painted green also, lend color to the city, but it is not from an artistic standpoint that this is done, but because the green copper paint is found to stand the severe climate better than any other.

Within the walls of the Kremlin are seven cathedrals, or churches, most of them rather small, but all of them gorgeous with pictures, gilding and jewels, and all of them of historic interest. In one, all the Czars are baptized and married, in another crowned, and in a third, until the time of Peter the Great, they were buried.

Within the same walls, too, are contained a large modern palace, which seems rather out of place amongst its mediæval surroundings, and also an Arsenal and a Senate house.

Ranged in row after row, in one of the court-yards of the Kremlin, are cannon marked with an "N" and the eagles of France, a souvenir of the visit of Napoleon in 1812. When the guns are returned to France, the outside world may begin to think that Russia has formed an alliance with France from friendly motives, and not merely for the purpose, simply and entirely, of furthering Russian aims.

One large Russian gun of Bronze, covered with ornamental devices and 24 inches in the bore, stands on a pedestal in a prominent position, with a pile of 24 dia. round iron shot in front of it, and is labeled, "The King of Guns," which sounds impressive, but it is needless to add that the gun has never been fired, nor would the label be of any further use should some rash experimenter undertake to do so. As a masterpiece of foundry work, however, the gun is very fine,

and is a good example of casting in bronze, for which the Russians have been noted for ages, as witness the famous bells cast by them at different times, the largest of which, weighing over 200 tons, stands in one of the squares of the Kremlin, just where it fell from the church tower above.

On our way to Russia we were just a little apprehensive, having read the usual highly-colored reports of the Russian police system, of possible difficulties with the officials there, from unwittingly breaking some of their rigidly enforced laws, or from expressing ourselves too freely upon the methods of government, or things in general. As a matter of fact, we found every official with whom we came in contact, railroad conductors, policemen or other government officials, courteous and polite, and we discussed politics and people with Russians, or amongst ourselves, as freely as at home.

There is a great latitude allowed to citizens of a foreign country, who are not required to become citizens of Russia unless they care to do so, not being subject to any disabilities on that account. The English Colony in St. Petersburg, composed largely of skilled artisans in the rolling-mills, ship-building yards, and cotton-mills, and numbering about 2,000, have their own churches and schools, which are regarded as under the jurisdiction of the English ambassador, and not subject to Russian laws. One curious case came to my notice of a young fellow of twenty-one or twenty-two years of age, who was introduced to me, at a friend's house, as an Englishman, and who was unable to speak a word of English. It seems his father, an English engineer, had married a Russian lady, and this boy had been brought up in the interior of the country, where nothing but Russian was ever heard, but, as his father was an Englisman, he, too, claimed the same nationality, which claim was allowed.

The censorship of the press is very rigidly enforced, though it seems a rather ridiculous waste of effort. Whilst we were in Russia the late Czar was already suffering from the sickness

which proved fatal, and for some inscrutable reason it was considered neccessary to prevent the people from knowing how seriously ill he was. The Russian papers, therefore, printed only what they were told regarding the Czar by the court officials, and all foreign papers were opened, and all references to the Czar completely blotted out, some of which papers I have. When, however, it became evident that recovery was almost hopeless, the facts were fully published and prayers offered in all the churches, not merely by the priests, but practically by the whole people, who seemed as much affected as if some member of their own family were in danger.

The system of village government existing in Russia, is a survival of the middle ages, and is for the most part a communal one. The land all round the village is frequently cultivated in common by the whole village, there are no hedges, no boundaries and no houses scattered about the country, the village usually consisting, in Southern Russia at any rate, of one wide street with whitewashed, detached stone houses, thatched with straw, on either side the street, every house looking alike, and when a young couple marry they add another house to the end of the line, which is sometimes miles long. If mining or timber felling is required to be done, a contract is made with the head man of the village, based upon the work performed, he furnishing all the labor and transportation required, the entire village frequently turning out if the contract is a large one.

The ordinary working dress of the peasant is simple in the extreme, consisting as far as can be seen of a fur cap, a sheepskin coat reaching to the knees, and high boots with thick felt tops. It is said that some of these coats last a lifetime, and to the casual observer some of them look as if they had been handed down from a remote ancestor, which impression is not by any means lessened when they come within range of one's olfactory senses. The holiday attire, especially of the peasant women, is picturesque, and usually gaudy, bright colors and

striking contrasts being much in favor, the arrangement of the dress, and the colors, denoting the district in which the wearer lives, just as the plaid shows the clan to which a Highlander belongs.

As no one can travel in Russia without passports, the peasants for the most part seldom leave the districts in which they are born, which, however, to them is no particular hardship, as a rule, nor have they any particular desire for the franchise, which to western nations appears so essential in theory, and which is so frequently abused, or neglected, in practice.

It is pretty safe to say that there are few Nihilists, or sympathizers with Nihilism, amongst the peasantry, these being drawn almost exclusively from the middle and professional classes, who know that there are many abuses, more particularly in the police and judicial system, which ought to be remedied, and yet which they are powerless to effect, and hardly dare discuss. These abuses exist in other places than Russia, but where the people have it in their own hands to effect a remedy, they are themselves responsible, and having no one but themselves to blame, are, consequently, much more disposed to be lenient.

The passport question, however, is one which does affect the traveler in Russia, as it must be presented and endorsed at every town where a stay is made over night. As far as possible the authorities endeavor to simplify matters, and it is merely necessary to hand in your passport to the hotel clerk, just as you register in an American hotel, but it must be properly endorsed before you can leave that town again, which may sometimes cause delay if you wish to leave suddenly, or on Sunday.

On the other hand the fact of your having a passport is a protection, and a properly endorsed passport guarantees you security and respect wherever you stay, although absolutely unknown except from your passport, and when driving at night

on the steppes, miles away from any habitation, or crossing the Volga at night, in the district where no doctor's life was safe during the cholera epidemic three years ago,—owing to the impression in the minds of the ignorant and violent peasantry that the doctors took cholera patients to the hospitals, and there poisoned them—it was reassuring to feel that the authorities of that district knew where I was; would know if any mischief befell me, and that the people with whom I came in contact also knew, that, in the event of harm happening to a traveler having a passport, they would be held responsible and severely punished.

The advantages, therefore, of the passport system in Russia, in my opinion, fully offset the disadvantages, and like many other customs which appear useless or absurd at a distance, it is found upon a closer and more intimate acquaintance with the working of them, under the conditions existing in that locality, that there is, just as there is of some other things Russian, something to be said on both sides.

Russia, to-day, offers a very inviting field for the establishment of manufacturing industries, especially in the direction of iron and steel, and more particularly as regards material required for railroads. The works visited by us were all running full time, on orders showing good profits, and the government had some large contracts for rails, locomotives and armor plates to give out, some of which have since been placed. At present the building of railroads is hampered by the difficulty of obtaining rails and equipment, and with the present capacity of the mills and factories, it will take years to make up the existing deficiency, without counting the extensive districts in Russia itself, outside of Siberia, which are without railroad communication of any kind.

Rails were worth \$47 to \$51 per ton in St. Petersburg, when we were there, or about \$40 at the mills in the south, there being a duty of \$20.50 per ton. Plates were worth about 4½ cents per pound, with a duty of \$29 per ton and

tyres 5½ cents per pound. The duty on light sheets amounts to \$34 per ton, and the selling price about 5 cents per pound.

As good pig iron can be produced in the south from \$17 to \$18 per ton, and rollers are paid from \$1.60 to \$1.70 per day in rail and structural mills ; puddlers and sheet rollers, \$1 to \$1.20 per day; helpers from 45 to 50 cents per day, and common labor 35 to 40 cents per day, it will be seen that there is a very fair margin between cost and selling price, though from the number of men employed, and the difficulty of getting material good enough to pass the government tests, the returns are not as large as they appear on the surface. Still, with modern machinery and assured government contracts, which would be necessary, as the government is by far the largest buyer, Russia appears to offer one of the best fields in the world for investment to-day.

Some informal talk followed the reading of the paper in which Mr. Hyde participated ; explaining and illustrating the subject further by means of a large map of the country visited.

Adjourned.

Daniel Carhart, *Secretary.*

MEETING OF THE CHEMICAL SECTION.

Allegheny, October 18th, 1895.

The regular meeting of the Chemical Section was held in the lecture room of the Carnegie Library Building, on the above date.

The meeting was called to order at 8.10 P. M. by Chairman J. M. Camp, twelve members and two visitors being present.

The minutes of the previous meeting were read and approved.

The Committee on Chemical Literature called the attention of the members to the following article :

"Ammonium Phosphomolybdate and the Reducing Action of Zinc in the Reductor," by A. A. Blair and J. Edward Whitfield in the Journal of the American Chemical Society, for October, 1895.

Mr. J. M. Camp, Chemist of the Duquesne Steel Works, read the following methods in use in his laboratory:

PHOSPHORUS IN PIG IRON AND STEEL.

Five grams pig iron or steel are dissolved in 60 c. c. 1.20 specific gravity nitric acid in a 12 ctm. porcelain dish, with watchglass cover; evaporated to dryness, still covered; and heated over lamp without cover till all acid fumes are driven off. When cool, dissolved in 30 to 35 c. c. strong hydrochloric acid and evaporated with watchglass cover till excess of free acid is driven off, as indicated by the first appearance of insoluble ferric chloride on bottom of dish. This is dissolved by adding two or three c. c. of strong nitric acid and the solution diluted with warm water to about 75 c. c., filtered, and washed into a 500 c. c. flask, using the 2 per cent. nitric acid wash water used in washing the yellow precipitate, to remove the last trace of iron. A slight excess of strong ammonia is then added—about 25 c. c., and then a slight excess of strong nitric acid—about 28 c. c., till the solution is a clear amber color.

The solution is heated or cooled to 85° C. and 75 c. c. molybdate ammonia is blown in by aid of a pipette; the flask is shaken for five minutes and allowed to stand till the supernatant liquid is clear. It is then filtered through a weighed filter that has been dried at 100° to 130° C. and weighed between watchglasses. The precipitate is washed with water containing 2 per cent. strong nitric acid, dried for one hour, or, till constant weight, at above temperature, and weighed between watchglasses. 1.63 per cent. of weight is taken for phosphorus.

MOLYBDATE OF AMMONIA.

Molybdate of ammonia is made by dissolving 225 grams molybdic acid in mixture of 600 c. c. water and 400 c. c. strong

ammonia, and adding this solution to 2,500 c. c. 1.20 nitric acid. This is kept in warm place over night and is ready for use.

PHOSPHORUS IN ORES.

The agate mortar sample is dried at 100° C. for one hour, allowed to cool, and 5 grams weighed off into a 12 ctm. porcelain dish with watchglass cover, 50 c. c. strong hydrochloric acid added and the solution allowed to go to dryness on the sand bath; 30 to 35 c. c. strong hydrochloric acid added, warmed, and when all in solution evaporated till first appearance of insoluble ferric chloride. This is dissolved by adding one or two drops strong hydrochloric acid and the solution diluted with hot water to about 75 c. c. and filtered into a 500 c. c. flask.

The residue is burned and fused with the mixed carbonates of potassa and soda, dissolved in hot water, acidified with hydrochloric acid and evaporated to dryness; moistened with dilute hydrochloric acid—1 acid to 2 water, diluted and filtered into the same flask with original filtrate, keeping as concentrated as possible. (This gives the silica, perfectly pure, of the five grams ore, on the filter paper ready for burning and weighing.)

A slight excess of strong ammonia is now added and then a slight excess of strong nitric acid and the process continued the same as for pig iron or steel.

To save time, the above process is modified as follows: Five grams of the dried ore in a 12 ctm. covered porcelain dish is boiled with 50 c. c. strong hydrochloric acid for about 30 minutes, or, till the ore is apparently all in solution, diluted with an equal volume of water and filtered into another dish of the same size. The residue is burned and fused with the mixed carbonates, dissolved in hot water, acidified with hydrochloric acid in same dish the original solution was made; and both solutions allowed to go to dryness on the sand bath.

30 c. c. strong hydrocloric acid is added to dish containing the original filtrate, and heated till all solution and the excess

of hydrochloric acid is driven off; dilute and filter into 500 c. c. flask. The fusion is moistened with dilute hydrochloric acid, diluted, and when in solution filtered into same flask with the last filtrate. The process is then carried on as before.

IRON IN ORES.

One gram of the agate mortar sample dried at 100° C. is weighed off into a No. 0 beaker with watchglass cover; 20 c. c. of strong hydrochloric acid added, and for a 60 per cent. ore 5 c. c. of the stannous chloride solution, and heated on sand bath till all in solution, and residue shows white. While still hot in same beaker add cautiously, drop by drop, more stannous chloride solution till the entire disappearance of the color due to the presence of the ferric chloride, and one drop in excess. Transfer to a No. 4 beaker containing about 300 c.c. cold water, and add 10 c.c. mercuric chloride solution and stir; let stand about one minute, and then titrate with potassa bichromate solution, until a drop of the solution added to a drop of potassa ferricyanide solution on a porcelain plate shows no green color on standing one-half minute. The number c. c. bichromate solution used gives the percentage of iron.

In case the residue shows presence of iron it is filtered, burned and fused with the mixed carbonates, dissolved in water and filtered; the oxide of iron on the filter is dissolved in dilute hydrochloric acid and allowed to run into original solution.

SOLUTIONS.

Strannous chloride solution is made by dissolving 300 grams of the salt in 500 c. c. strong hydrochloric acid and 500 c. c. water; 1 c. c. will reduce about one-tenth gram iron.

Mercuric chloride solution is made by dissolving 50 grams of the salt in 1,000 c. c. water.

The ferricyanide solution is made by dissolving about .05 grams of the salt in 50 c. c. water.

The potassa bichromate solution is made by dissolving 8.9 grams of salt to the litre water and standardizing with iron wire,

standard steel or ore, and diluting so that 1 c. c, equals one per cent. iron; proving strength of solution after dilution with the standard steel or ore.

MANGANESE IN ORES.

The agate mortar sample is dried for one hour at 100° C., allowed to cool, and five grams weighed off into a 12 ctm. porcelain dish with watchglass cover, 50 c. c. strong hydrochloric acid is added and the solution allowed to go to dryness on the sand bath.

The residue is moistened with dilute hydrochloric acid—one acid to two water—diluted, heated till all in solution and filtered into a 500 c. c. graduated flask. The residue is burned and fused with five to ten times its weight of the mixed carbonates of potassa and soda. If fusion shows presence of manganese it is dissolved in hot water, acidified with hydrochloric acid, evaporated to dryness, taken up as before and filtered into same flask with original filtrate.

The solution is cooled, diluted to the mark, and with the aid of an exactly agreeing pipette 100 c. c.—equal to one gram of ore—taken as many times as desired into No. 4 Beakers 30 c. c. strong nitric acid added and the solution evaporated to small bulk—10 to 15 c. c.; 75 c. c. strong nitric acid is now added and the solution heated to boiling, and while boiling, an excess of potassa chlorate added in small portions and boiled a few minutes after the final puff.

The solution is cooled and filtered through a purified asbestos plug with the aid of suction. Beaker and plug washed twice with strong nitric acid and plug blown back into beaker in which precipitation was made. The filtering tube is washed off with water and dilute hydrochloric acid to dissolve any adhering precipitate, and 25 c. c. strong hydrochloric acid added to beaker, and 1 to 2 cc. dilute sulphuric acid to precipitate any

barium that may be present. (See foot note.) The solution is heated to boiling, keeping the beaker constantly agitated to avoid bumping, and when all the binoxide of manganese is dissolved, filtered into a 500 c. c. flask from the suspended asbestos.

The solution is neutralized with ammonia till a faint permanent precipitate of ferric hydrate is formed, 10 to 15 c. c. of a 25 per cent. solution of ammonia acetate added and the solution heated to boiling and set aside to settle. Filtered into a 500 c. c. flask with aid of suction and flask and funnel washed once with hot water. The precipitate is dissolved in dilute hydrochloric acid into same flask precipitation was made, and a second basic acetate precipitation, made as before, filtered into same flask containing first basic acetate filtrate, and flask and funnel washed twice with hot water.

The subsequent precipitation can be made in the flask, or, the united filtrates are transferred to a No. 6 beaker—carefully rinsing out flask; and ten c. c. acetic acid added. The solution is heated to boiling and 5 to 10 grams ammonia phosphate crystals added, and the solution stirred till the precipitate assumes the well-known crystaline form; 25 c.c. strong ammonia is now added and the solution stirred for a few minutes till the precipitate is all crystaline, and set aside to settle. Filtered through an 11 ctm. filter paper by aid of suction and washed with hot water, burned and weighed as $_2Mn\,O,P_2O_5$. 38.74 per cent. of weight is manganese.

When a single analysis only is required, one gram can be weighed off and treated as directed for five grams: But if more than one are to be made and the residue fused, which should be done in all cases, unless absolutely certain it contains no man-

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NOTE.—At this stage of the analysis, if there is baryta in the ore, which is usually the case, the nitrate is very insoluble in strong nitric acid, and wholly or in part separates out; consequently it will be filtered off with the manganese binoxide, and will ultimately go into solution in the subsequent dilution and boiling with hydrochloric acid. This must be separated by addition of sulphuric acid, and sufficient time allowed to precipitate, or it will be weighed with the manganese as pyrophosphate.

ganese, as a silicate of manganese exists that looks and burns perfectly white, then it is preferable to start with five grams as directed.

MANGANESE IN STEEL AND PIG IRON.

From two to five grams of the steel or pig iron are weighed off into a No. 4 beaker with watchglass cover, the least amount necessary of 1.20 specific gravity nitric acid for complete solution added, and heated to boiling. When all in solution the watchglass cover is removed and the solution evaporated over lamp till the excess of nitric acid is driven off, as indicated by the first appearance of the insoluble nitrate of iron in the solution; 75 c. c. strong nitric acid is added and the solution heated to boiling, and while boiling an excess of potassa chlorate added in small portions and boiled a few minutes after the final puff. Cooled, and filtered through a purified asbestos plug, with the aid of suction, beaker and plug washed twice with strong nitric acid and blown back into beaker in which the precipitation was made, the filtering tube is washed off with water and dilute hydrochloric acid to dissolve any adhering precipitate, an excess of strong hydrochloric acid added and the solution heated to boiling till the binoxide of manganese is all in solution; filtered from the suspended asbestos, and the analysis finished same as for manganese in ores.

In case of a pig iron high in silicon, it is preferable to dissolve in hydrochloric acid, evaporate to dryness to separate silica, moisten with dilute hydrochloric acid, dilute and filter. To filtrate, add an excess of strong nitric acid—at least 75 c.c., if five grams of iron were taken, and evaporate to total expulsion of hydrochloric acid. 75 c. c. strong nitric acid added and the solution heated to boiling, and while boiling an excess of potassa chlorate added, and the analysis finished same as for manganese in steel.

MANGANESE BY COLOR.

Two-tenths gram pig iron or steel and standard steel of known manganese contents, are weighed off into 1 inch by 10

inch test tubes; 30 c. c. nitric acid 1.20 specific gravity added to each and heated over argand burner till dissolved, and boiled till all the nitrous fumes are driven off. While boiling, about one gram peroxide of lead is added and boiling continued for one minute, and test tubes set in cold water bath to settle. When cool, and the supernatant liquid is clear, the tube containing the standard solution is decanted into one of the comparing tubes; this can be very safely done without losing more than a drop of the solution, and without a particle of the lead peroxide entering the comparing tube. The solution is then diluted to twice the number c. c., the steel contains hundredths per cent. manganese, and mixed thoroughly. The test, pig iron or steel, is decanted in like manner into the other comparing tube, and diluted with cold water to like colors. One-half the reading in c. c. is hundredths per cent. manganese.

In case the manganese is high in the sample—.75 per cent. and upwards—the test and standard are each boiled two minutes after the addition of the lead peroxide, otherwise the treatment is the same. The print of the color tubes used shows plainly their advantages over the ordinary tubes.

SILICA IN PIG IRON.

Twice the factor weight—.9404 grams of the drillings—are weighed off into a 12 ctm. porcelain dish, and 25 c. c. added of the mixed acids, nitric and sulphuric—mixed in the proportion of 18 c. c. of 1.20 specific gravity nitric acid and 7 c. c. half-and-half sulphuric acid—heated over argand burner till all in solution and afterwards to dryness and finally until dense white fumes of sulphuric acid are given off. Allowed to cool, moistened with dilute hydrochloric acid—1 acid to 2 water—diluted with hot water and warmed till all in solution, filtered, washed with hot water and dilute hydrochloric acid till free from iron, burned and weighed. One-half the weight in decimilligrams is hundredths per cent. of silicon.

SULPHUR IN PIG IRON AND STEEL.

AQUA REGIA METHOD.

Five grams pig iron or steel are weighed off into a No. 5 beaker, with watchglass cover, and 50 c. c. aqua regia added at one time, freshly made up, by adding 45 c. c. strong nitric acid to 5 c. c. strong hydrochloric acid. When the violent action has ceased, heat is applied till all is in solution, and evaporated, still covered until the bulk of the solution is considerably reduced, an excess of strong hydrochloric acid is then added,—about 40 c. c.—to displace all the nitric acid, and the solution after continued evaporation is finally transferred to a 12 ctm. porcelain dish, and allowed to go to dryness on the steam bath—35 c. c. strong hydrochloric acid added and warmed till all is in solution and evaporated till the free hydrochloric acid is driven off, as indicated by a film of ferric chloride floating on the surface. This is dissolved by a drop or two of strong hydrochloric acid, and diluted to about 75 c. c. and filtered into a No. 2 beaker, washing with hot water and the least amount necessary of dilute hydrochloric acid to remove the last trace of iron. Heated nearly to boiling and 10 c. c. of a 5 per cent. solution of barium chloride added, and the solution set on sand bath and evaporated to the presence of the insoluble ferric chloride as before.

This is dissolved with a drop or two of strong hydrochloric acid, and with a wash bottle a strong stream of cold water is blown into the beaker, thoroughly stirring up the solution, till its volume is about 175 c. c. and set aside in a cool place over night. Filtered through a double 7 ctm. filter and washed with hot water and dilute hydrochloric acid till free from iron—burned in an open crucible, and weighed. 13.756 per cent of weight is sulphur.

SULPHUR IN PIG IRON AND STEEL.

IODINE METHOD.

Five grams pig iron or steel are weighed off into a dry 500 c. c. flask, provided with a double perforated rubber stopper,

with a long stem four ounce funnel tube with a stop-cock, and a delivery tube bent at right angles, on which a short piece of $\frac{1}{4}$ inch rubber tubing is placed, making connection with a delivery tube, also bent at right angles reaching to the bottom of a one nch by 10 inch test tube, suitably supported. About 10 c. c. of the ammoniacal solution of cadmium chloride is introduced into the test tube, which is diluted with cold water, until the tube is about two-thirds full. 80 c. c. of dilute hydrochloric acid—one acid to two water—is poured into the funnel tube, a file mark on the bulb indicating this amount, which is allowed to run into the flask, the stop-cock is then closed, and a gentle heat applied, till the drillings are all in solution, and finally to boiling by raising the light, until nothing but steam escapes from the delivery tube.

The apparatus is then disconnected, and the delivery tube is placed in the No. 4 beaker in which the titrations are made, the contents of the test tube are then poured into the beaker, the test tube filled to the top twice with cold water, the sides of the tube rinsed down with about 25 c. c. dilute dydrochloric acid, and filled again with cold water. The total volume of the solution equaling about 400 c. c., both acid and water being supplied from overhead aspirator bottles and suitable rubber connections with pinch cocks, the delivery tube is now rinsed off inside and out with dilute hydrochloric acid, and about 5 c. c. starch solution added to the beaker.

Without waiting for complete solution of the cadmium sulphide, the iodine solution is run in from a burette, stirring gently, till a blue color is obtained, the solution is then stirred vigorously, keeping a blue color by fresh additions of the iodine solution, till the precipitate of cadmium sulphide is all dissolved, and the proper permanent blue color is obtained. The amount of iodine solution used in c. c. is hundredths per cent. sulphur.

Iodine Solution is made by weighing off into a dry 500 c. c. flask, about 35 grams potassa iodide, and 16 grams iodine, 50 c. c. water added and shaken and diluted cautiously until all

in solution, and finally diluted to 3500 c. c. This is standardized with steels of known sulphur contents, so that 1 c. c. equals .0005 grams sulphur.

Cadmium Chloride Solution is made by dissolving 100 grams cadmium chloride in one litre water, adding 500 c. c. strong ammonia, and filtering into an 8 litre bottle, 2 litres of water are now added, and the bottle filled to the 8 litre mark with strong ammonia.

Starch Solution is made by adding to one-half gallon boiling water, in a gallon flask, about 25 grams pure wheat starch, previously stirred up into a thin paste with cold water; this is boiled ten minutes and about 25 grams pure granulated zinc chloride dissolved in water added, and the solution diluted with cold water to the gallon mark. The solution is mixed and set aside over night to settle, the clear solution is decantered in to a glass stoppered bottle for use.

This solution will keep indefinitely.

NICKEL IN STEEL.

Our determinations of nickel are made exclusively in machinery steel, pinions and rolls; the amount ranges from 2.5 to 3.5 per cent. No attempt is made to separate cobalt, as it seldom occurs in the steel, and when present, is derived from the nickel ores in inconsiderable amounts. The method is as follows:

Dissolve one gram of steel in 15 c. c. 1.20 specific gravity nitric acid, in a No. 3 beaker—transfer to a litre flask and dilute with hot water to about 700 c. c. Neutralize the excess of acid with ammonia, and add about 15 grams acetate of soda in crystals. Heat to boiling and boil one-half minute, let precipitate subside and filter through an eleven inch pleated filter, into a large beaker. Let precipitate thoroughly drain, perforate filter, and wash precipitate back into flask in which precipitation was made, wash filter with dilute hydrochloric acid and water till free from iron, and add a slight excess of hydrochloric acid

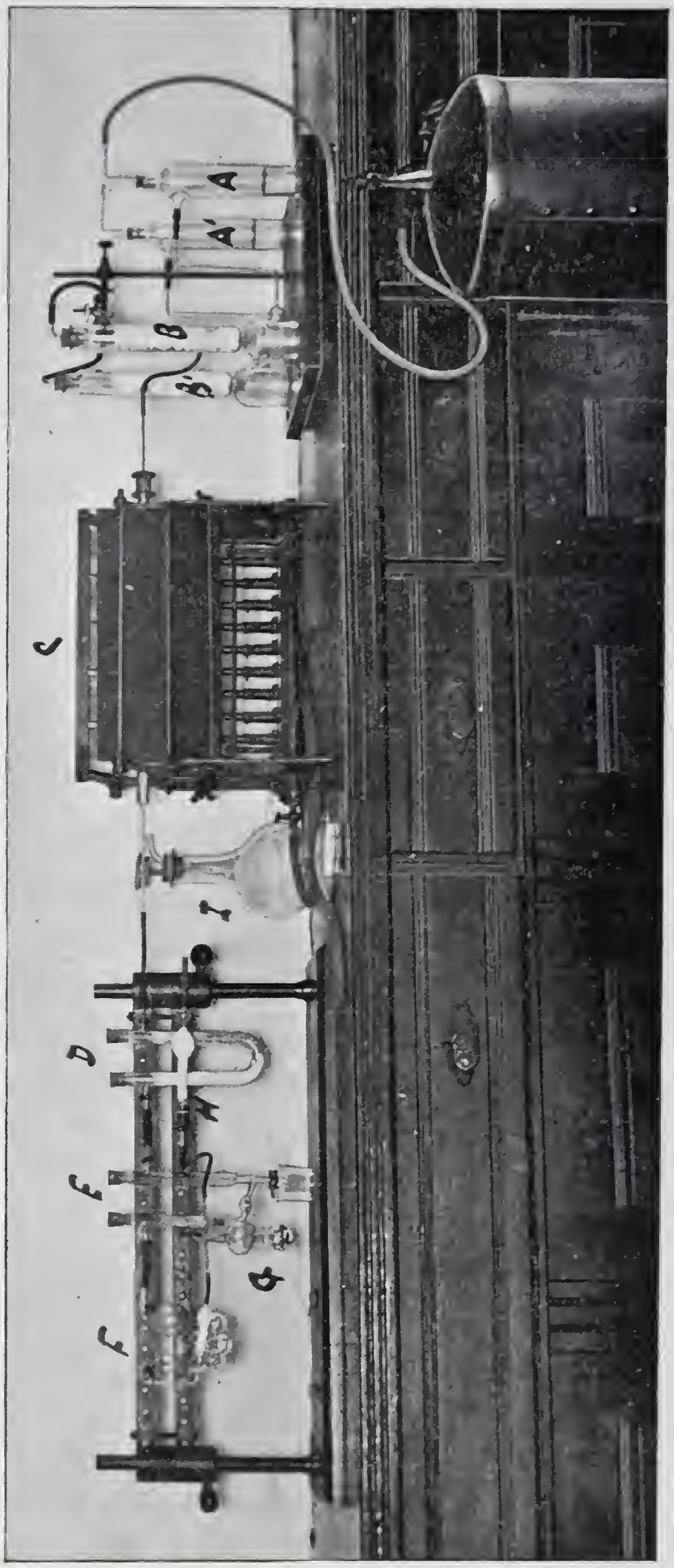
to flask, to dissolve all the precipitate, and dilute to about 700 c. c. Neutralize and make second basic acetate precipitation and filtration as before.

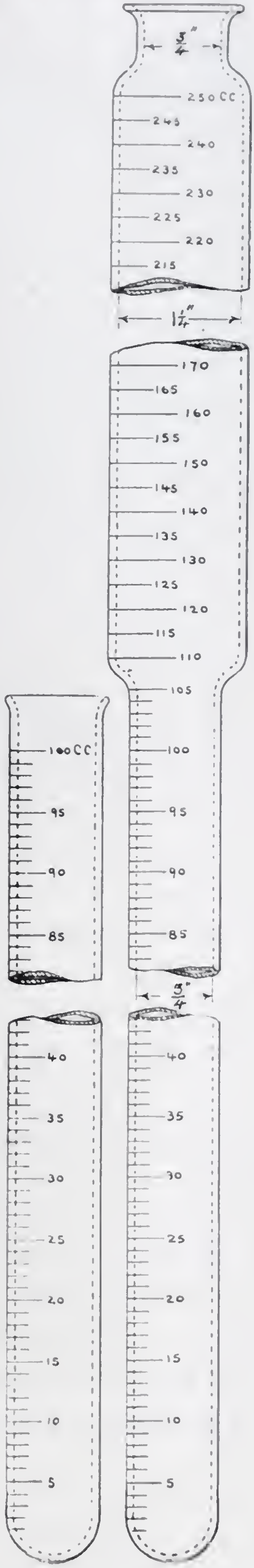
Unite filtrates, make faintly ammoniacal and heat nearly to boiling. If traces of iron separate, filter, and in filtrate pass hydrogen sulphide till the solution smells strongly of gas. Make slightly acid with acetic acid, testing with litmus paper, and set on steam bath until the precipitate of nickel sulphide agglomerates. Filter wash with hot water, burn in the hottest part of the muffle and weigh as Ni O—78.58 per cent of weight is nickel.

In case copper is present in any appreciable amount, dissolve the precipitate of nickel suphide in hydrochloric acid with the aid of potassa chlorate, filter from the paper, dilute, warm and precipitate the copper with hydrogen sulphide, let subside, filter wash, and if desired burn and weigh. To the filtrate add ammonia in slight excess, pass hydrogen sulphide, let precipitate subside, filter wash, burn and weigh as Ni O, as before.

CARBON BY COMBUSTION IN STEEL.

From one to ten grams of steel are weighed off into a dry beaker of suitable size, and from 100 c. c. to 500 c. c. of the double chloride of copper and potassa solution added. This is made by dissolving five pounds of the double chloride of copper and potassa, in five litres of water, filtering through a purified asbestos plug, and adding 250 c. c. or 5 per cent. strong hydrochloric acid. The beaker is placed on a suitably arranged stirring apparatus, making about 250 revolutions per minute, and kept at a temperature of about 50° C. till all is in solution. When permissible it is preferred to allow the solution to cool, and the carbonacious residue to subside before filtering. The solution is then filtered through a perforated platinum boat, with suitable asbestos blanket, and washed once with dilute hydrochloric acid, and then warm water, letting all the washings run from the beaker into the boat. The boat is then dried at about 85° C. and is finally transferred to the platinum combustion tube.

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The accompanying photograph shows the arrangement of the apparatus. In front of the combustion furnace C is the double purifying train for oxygen and air, the first tubes A and A, contain a strong solution of caustic potassa of 1.4 specific gravity. This strength solution is also used in the potash bulbs. Tubes B and B are filled to the top with stick caustic potassa in short pieces. These tubes are connected by means of a three way tube, with suitably arranged stop cocks and rubber tubing, with the platinum combustion tube, resting in a ten burner furnace C. The tube is $\frac{5}{8}$ inch inside diameter and 17 inches long, provided with a gas tight joint, and 6 inch continuations at each end 3-16 inch inside diameter. Two inches from the rear end of the tube is placed a coil of platinum gauze 2 inches long, completely filling the tube, then 2 inches of coarse lumps oxide of copper, and 2 inches more of platinum gauze.

After the combustion tube comes the 6 inch purifying U tube D, the first half of which is filled with granulated anhydrous cuperous chloride and the second half with anhydrous sulphate of copper. After this comes the special U tube E, containing about 10 c. c. strong sulphuric acid, the last half of the tube contains broken glass rods to diminish the air space. Then comes the potash bulb E, with a drying tube with ground glass joint, and filled with freshly burned calcium chloride, after this a potash bulb G, containing strong sulphuric acid, and lastly the safety tube H, filled with calcium chloride.

It will be observed that sulphuric acid is used as a drying medium both before and after the potash bulb, as the writer doubts the practicability of constantly moistening the gases to the proper degree with a plug of moist cotton, and prefers rather to dry the gases perfectly before entering the absorption tube, and by means of the sulphuric acid tube to catch any moisture taken up from the potash bulb, which will be weighed and its gain added to the gain of the potash bulb.

The combustion is proceeded with as follows: After the

introduction of the boat into the combustion tubes the oxygen is started flowing through the apparatus, at the rate of three bubbles per second in the potash bulb. The burners under the platinum gauze and oxide of cotton are ignited, and after the tube has acquired a full red color, the burners in front of the boat are ignited, and gradually approaching the boat till all are burning and the tube throughout is a full red. This is continued for 15 minutes, then the oxygen is shut off, the burners extinguished, and air is aspirated or forced through the apparatus, at the same rate as the oxygen, for 15 minutes. The two tubes are then disconnected, the small caps placed on the ends, and each of them weighed, the gain in the tube containing the sulphuric acid being added to the gain of the potash bulb. Three-elevenths of the total gain is carbon. These weights are taken as the first weights of the succeeding combustion. At the beginning of a series of combustions, a blank analysis is run to get the first weights.

The papers were discussed by H. S. Menough, Dr. Stahl, G. O. Lœffler, W. E. Garrigues and others.

Adjourned at 10 P. M.

A. D. WILKINS,
Secretary C. S.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

ANNOUNCEMENT.

In the future the Society will mail to its menbers and correspondents, postage prepaid, ten monthly pamphlets yearly ; each one including, when practicable, the minutes of and the papers read at the regular meeting, and meeting of the Chemical Section of the preceding month.

The pamphlets are for sale at 75 cents each. Subscription price, $7.00 per annum.

In addition, any paper which the author desires to be distributed before being read will be mailed separately.

The following Rule of the Board of Directors is in force :

An author of a paper is entitled to twenty-five copies, if printed. In addition he can purchase fifty or more copies extra at first cost to the Society, plus 10 per centum, provided the order is forwarded before the type is distributed. These papers can be issued with pamphlet covers when desired.

With the publication of Volume X, the printing and binding of our TRANSACTIONS as an Annual, by the Society, ceased. The paging of the Monthly numbers, however, will be made consecutive, and at the end of the year a title page and index will be provided, so that members may have them bound into a volume uniform with preceding ones.

Copies of Volume X. for 1894 will be mailed to each member who has paid his dues for 1894, upon the receipt of 15 cents for paper covered or 35 cents for cloth bound.

Extra copies of Volume I. in paper, and of Volumes V., VI., and VII. in paper or cloth, will be mailed to members on receipt of 75 cents for paper covered, and $1.00 for cloth bound copies. The corresponding prices for Volumes VIII, IX or X, are $1.00 for paper and $1.25 for cloth bound copies.

A few copies of single papers unbound will be carried. These can be purchased by members at a rate of 1 cent a page, no paper to cost less than 10 cents.

In order to keep the cost of publication of papers within the limits of the resources of the Society, the Board desires to impress on all authors the necessity of restricting their illustrations to single page and to a limit of three pages. The Board reserves the right of supervision of papers and illustrations.

In regard to preparing drawings for publications: Tracings only can be used, and these must be in strong lines and strong lettering. The author must make all tracings subject to reduction to 6½ inches in one dimension. The size of a single page of our publications is 6½x4 inches. Pull outs may be in multiples of the 4-inch dimension, but must not exceed 6½ inches in the other. Many tracings may be made so strong by using black ink and wide lines that reduction is possible across the page. All tracings can be reduced six to one. [Before any illustrations are reproduced the author must submit his tracings to the Board of Direction.]

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

ALLEGHENY, PA., NOV. 21st, 1895.

The regular meeting of the Engineers' Society of Western Pennsylvania, was held at 8 o'clock in the lecture room of the Carnegie Library Building, Allegheny, on the evening of the above date.

President Johnson occupied the Chair and there were fifty members and visitors present.

The minutes of the October meeting were read and approved.

The Secretary presented the names of five applicants for membership who were approved by the Board of Direction, and who will be voted on at the next meeting.

The President appointed the following named gentlemen a committee to nominate officers for the ensuing year and to report at the next meeting:

COMMITTEE.—Emil Swensson, Chairman, W. E. Koch, C. F. Scott, F. Z. Schellenberg and J. M. Deforth.

It was moved by Mr. Swensson that the Society have a banquet some time during the last of January next. Seconded and Carried.

It was voted that the Reception Committee make the necessary preparation and take charge of the entertainment.

Mr. Henry W. Fisher then read his paper, entitled: "The Manufacture, Testing, Installation and Operation of Underground Electric Cables."

THE MANUFACTURE, TESTING, INSTALLATION AND OPERATION OF UNDERGROUND ELECTRIC CABLES.

Knowing that this Society is composed largely of persons who are engaged in mechanical and civil engineering professions, I have endeavored to avoid electrical technicalities of a complex nature, and to confine myself mostly to a practical treatment of the subject. Through the kindness of the Standard Underground Cable Company, the Allegheny County Light Company, and the Central District and Printing Telegraph Company, I have before me a number of electrical instruments, samples of cables, terminal boxes, etc., which I will mention in detail later on.

The history of underground electric cables commences about the year 1845, when Wheatestone and Cooke took out a patent, claiming a combination of separately insulated wires enclosed in a lead tube; the lead was moulded around the wires by hydraulic pressure. These early attempts at the manufacture of lead-covered cables were not very successful, owing, no doubt, to the imperfect machinery employed. The wires were usually covered with some fibrous material, and afterwards saturated with compound or white lead. About the year 1846 gutta percha was first used for insulating wires, and in 1858, through the efforts of Cyrus W. Field, the first Atlantic cable was laid. This cable only lasted a few days; the Civil War delayed Mr. Field in his efforts to establish telegraphic communication with England, but in 1866 his earnest efforts were abundantly rewarded by success, and he was the recipient of many honors, both here and abroad. Genuine specimens of the first Atlantic cable are extremely rare and valuable, but through the kindness of Mr. T. Waters, of the Standard Underground Cable Company, I have before me a sample, which will be on exhibition after the reading of this paper. The process of manufacture of the Atlantic cables is primarily as follows: The center conductor is composed of a number of

strands of fine wire twisted together, so as to insure flexibility. This strand is thoroughly saturated in Chatterton's compound, after which the gutta percha is placed compactly around the conductor. The early method of manufacture was to put the gutta percha on in several thin layers, between each layer being a covering of Chatterton's compound; the present method, however, is to completely insulate the conductor in one operation. After the conductor thus insulated has been carefully tested, it is served with several coverings of moist, tarred hemp, the function of this being to act as a cushion to the insulated wire. The next operation is to wind spirally around the outside of the cable a number of steel wires, which forms the armor to give the cable strength against subsequent mechanical strains. Finally, this armor is served with a covering of tape, saturated in asphaltum or tar. The cable when completed and ready for laying is continuously coiled in large tanks, from which it is transferred to other suitable tanks in the steamship. The tanks in the factory hold between 200 and 400 miles of cable each. The following data with reference to the Makay-Bennett cable, laid in 1884, may be found of interest: The outside diameter of the shore end cable was $2\frac{1}{2}$ inches; of the deep water cable, 1 inch. The gutta percha used was imported from Java and Summatra, and cost about 75c per lb. The weight of the conductor per nautical mile was 250 pounds; the weight of the gutta percha per nautical mile was 300 pounds; weight of the deep sea cable complete, five tons per nautical mile; weight of the shore ends, twenty tons per nautical mile. The shore ends of submarine cable are usually laid first, and afterwards the deep sea cable. The shore ends of the cable out at sea are securely fastened to buoys, to which are attached suitable chains and anchors. They remain in this position until such time as the deep sea cable is ready to be jointed to the shore ends, when the buoy is relieved of its moorings, and hoisted on board the vessel. The joint is then made, and the cable dropped overboard. During

the process of laying, the following measurements are made: The insulation resistance of the conductor, the end pull or tension of the cable, the rate of paying out of the cable, and the speed of the vessel. The difference of the last two is a measure of the irregularities at the bottom of the ocean. Care has to be taken that the tension is not too great to injure the cable, or to cause it to span, under undue strain, long distances between elevations at the bottom of the ocean. Before laying the submarine cable between Cadiz and the Canary Islands, a bank was discovered at a depth of 65 fathoms. Soundings showed that there was almost a precipitous fall to a depth of 2,000 fathoms shortly after leaving this bank. An attempt to have laid a cable at this point would certainly have been disastrous to the cable, and another location was selected. The rate of laying cables varies from five to nine knots an hour.

I have here on exhibit a cable splice showing how the sections of an Atlantic cable are jointed.

Shortly after the first use of the gutta percha for submarine cables, India Rubber began to be used as an insulating cover for telegraph wires. The early attempts in this direction resulted in very many failures, and even now the life of a rubber cable is short, owing to the deterioration brought on by moist and dry atmospheres, and changeable temperature. The rubber is formed around the conductor by screw pressure in a machine which is known to the trade as a stuffing machine, or it is first callendered into big sheets of the proper thickness, and cut into strips of the width necessary to entirely enclose the wire by pressing the strips through sets of rolls made with great exactness. Rubber covered wire gives excellent service in buildings where it is not exposed alternately to damp and dry atmospheres, but for out of door work, especially in underground conduits, its life, is comparatively short. It used to be thought that rubber covered wire enclosed in a lead tube would last forever, provided, of course, that the lead was not injured in any way, but the recent failures of such

cables in New York City leads one to the general belief that the life of a rubber covered cable, even under such favorable conditions, is of comparatively short duration.

We next come to a type of cable which is probably more extensively used than any other in this country, namely, one in which the insulating material is of a fibrous nature, thoroughly saturated with an insulating compound, such as some of the different forms of petroleum residium, or rosin oil. The fibrous medium, composed of jute, cotton or paper, is wound by suitable machinery around the conductor, after which the whole is thoroughly insulated by submerging it in a tank of boiling insulating compound. It remains in this tank until all moisture has been expelled, when it is transferred to the cable lead press, where a lead tube is formed around the central core by hydraulic pressure. The conductor of large electric light cables is composed of a number of strands of small wire, so as to insure flexibility. The thicknesss of the insulating material of electric light cables ranges from 3-32 to 1-4 of an inch, depending upon the voltage to which the cable is to be subjected.

The thickness of lead is usually 1-16 to 1-8 of an inch, depending upon the size of the cable.

Telegraph cables are composed of a number of separately insulated wires, which are built up in a number of layers, each layer being applied in reverse direction spirally around the preceding wires, very much in the same manner as in the manufacture of cable ropes.

Telephone cables are made up of a number of twisted pairs, in the same manner as has just been described under telegraph cables. The insulating material in this cable is generally paper. The object of twisting the conductors in pairs is to eliminate induction and cross talk, which is so annoying on telephone circuits, where a ground return is used. Twisted pairs are always used on long distance telephone circuits, and in fact wherever long distance telephones are used, and this is primarily the reason why the transmission

through such an instrument is so perfect. Dry paper is used as the insulating material, both on account of its low specific inductive capacity, and because it can be formed loosely around the conductor, so as to include a lot of air, which has practically the lowest electrostatic capacity of all known substances.

Sometimes the lead of the cable has to be tinned by passing it through a molten bath of tin. The object of this is to preserve the lead from being eaten away by chemical action. At other times the same end is accomplished by covering the cable with a heavy braid, which is saturated with a preservative paint, such as P. & B. compound.

LAYING OF CABLES.

In the early days, cables were frequently laid in a wooden box, which was afterwards filled with pitch, and in a number of cases this method of laying proved very successful, but the cable was so frequently injured through carelessness upon the part of workingmen, who were employed in opening streets for the purpose of laying water or gas pipes, that this method of laying cables is very seldom used now. One other radical defect was that a cable thus laid is more easily subject to be destroyed by electrolytic action than when placed in a regular duct, the reason for this being that the cable is partly insulated throughout most of its length, and hence the electrolytic action is more intense at weak points, where moisture happens to reach the lead.

The general method of laying cables now is to place them in previously constructed ducts, made of wood, iron, cement lined, or terra cotta tubes. Access to these ducts is obtained through manholes, which are generally placed near the intersection of streets. In order to get a rope through these ducts, for the purpose of pulling the cable through, a number of short rods are fastened consecutively together, down in the manhole, and shoved through the duct until the first rod reaches the next manhole. A wire is then attached to one end

of this chain of rods, and pulled through the duct, each rod being disconnected in turn, till the end of the wire is obtained. A rope is then attached to the wire, and pulled through the duct. The end of the cable is fastened securely to this rope, and by means of a suitable winch, the cable is pulled through. The ends of the cables are always carefully soldered, so as to preclude the entrance of moisture. The jointing is done by means of a man who is skilled in the art of plumbing, and making good wire connections. The conductors of electric light cables are always carefully soldered, but the general practice is to use a good twisted joint on telephone and telegraph cables. The joints are all carefully taped, and insulated with hot compound. When this work is completed, a lead tube is wiped by a plumber's joint to the lead at each side of the wire joints. The tube is subsequently filled with a hot insulating compound, and the hole through which the insulating material is poured is afterwards carefully soldered. The ends of the cable are protected from moisture by means of hard rubber terminals, or iron terminals in which are fastened a number of hard rubber bushings, with suitable brass screws through them. I have on the table a number of terminals which illustrate the general practice in this direction. I have also some sample of lead sleeve joints, one of which was made by a mould especially designed for this work. There are also on the table, samples of wire joints which have been made according to the general practice.

OPERATION OF CABLES.

In the operation of underground electric cables, there are a number of things which have to be guarded against, namely:—

1. Overheating of the conductor by excessive electric currents.

The laws governing the rise of temperature, with increase of electric current, are now so well known that there is really no reason why a conductor should be overheated. Carelessness, however, in this respect, has sometimes been the cause of

fires. The accidental crossing of small wires, such as are used for telegraph or telephone purposes, with the electric railway or street service lines, occasionally causes the excessive heating or fusion of the smaller wires. I have seen samples of a cable containing small conductors, in which the insulation had been completely charred, through overheating of the wire. The trouble in this direction of overheated conductors, lead electric and insurance companies years ago, to adopt a large factor of safety in specifying the amount of current to be used on wire of a given diameter, and used under specified conditions. In most cases a current sufficient to cause a rise of 20 or 25 degrees in the conductor, above the temperature of the surrounding air, was considered a safe carrying capacity. On account of the difference in the radiation of the heat, it is necessary to know whether the wire is bare or insulated, and whether it is exposed to the air, or is placed in a concealed position in the walls of the buildings, or in underground electric cables. The formulæ for this work are numerous, but as we are dealing more specifically with cables, I will give one which is the result of some extensive tests I made several years ago on several different sizes of cable, and is based on a rise of 16 degrees Fahr.

Let A = the amount of current expressed in amperes.

Let D = the diameter of the cable expressed in 1-1000″ or mils.

$$\text{Then } A = \frac{D^{\frac{3}{2}}}{44.6} \qquad (1)$$

2. Injury to the insulation by excessive voltage.

The distance through which an electric current will spark in air, depends upon the number of volts of electric pressure. Hence, in ordering a cable, it is necessary to know what the maximum voltage will be. Experience has shown that it is necessary to use a very large factor of safety in this respect also, and hence cables will usually stand two or three times the electric pressure to which they are to be subjected normally.

There are certain conditions depending on the self induction and capacity of the cable and dynamo, which may cause a sudden momentary rise of voltage, that may be twice or even three times the normal voltage. If the insulation is not strong enough to resist this, the cable is apt to be burned out. Telephone and telegraph cables which are not designed for a high voltage, occasionally become crossed on the overhead lines with high voltage circuits, and the insulation is sometimes injured from this cause. The distance through which a given voltage will spark in air, depends upon the nature of the points used. The distance is generally greater for sharp points than for rounded surfaces. This may be considered true for one or two thousand volts, but I have sometimes got a good deal longer spark distance with 6,000 volts by filing the least bit off the point of a needle. If too much is taken off the needle, the spark distance drops and becomes much less than it would be for a real sharp needle. This leads one to the general belief that for these higher voltages, there is a certain character of point which will give a maximum spark distance, and I am inclined to the general belief that if small enough circular points could be made accurately, and of sufficient variation in diameter to determine which point would give the maximum spark length for a given voltage, the very interesting relation between the curvature of the point and the maximum spark length at a given voltage could be developed. According to some experiments made by the writer, in which some No. 10 Sharp's needles were used, the law giving the relation between the sparking distance in air, and the voltage over a range of from 1,000 to 10,000 volts, is as follows:–

Letting S = the length of spark gap in inches.

Letting V = the electric pressure in true volts.

Then $S = .0000593\ V - .006$.

(2)

The tests to determine this law were made with the alternating current, and Westinghouse transformers were used to

obtain the different voltages. The current was taken from the Allegheny County Light Co's. service, and was generated by a 400 light alternating current dynamo, using a toothed armature. The voltage as generated by such a dynamo varies from zero to a maximum, and back to zero at the rate of 266 times a second. The length of spark is determined by the maximum voltage at any time, and as the maximum voltage in this case is about 1.4 times that measured by the alternating current voltmeter, formula 2 becomes (3) $S = .0000424\ V - .006$, in which V represents the maximum voltage, or in the case of the direct current system, the regular voltage as measured by an ordinary volt meter. The spark distance of a given voltage in air is very much reduced, when a solid or liquid insulating material is placed between the points, for instance, by an actual test 6,000 volts alternating current, only sparked .027 inches through plain paper, while by formula 2, the distance in air would be .350 inches, or 13 times greater distance than through paper. By an actual test, the resistance to the passage of a spark in refined petroleum oil was 27.2 times greater than in air. The spark distance in air is much reduced when rounded surfaces are used instead of points. The spark distance between balls measuring .358 inches in diameter, with 6,000 volts pressure, was .087 inches, or a little less than $\frac{1}{4}$ the distance between sharp points in air, for the same voltage as given above. Equation No. 2 above being of the first degree, can be represented by a straight line, but when balls are used this is no longer true, and the equation showing the relation between spark distance and voltage becomes very complicated. The curve showing the relation between spark distance and voltage for the balls already mentioned above, looks very much like a curve of sines imposed upon another curve. The subject of sparking distances is most interesting from a scientific standpoint, but I will have to leave it now, and go on with the more practical part of the subject.

3. Mechanical Injuries to the Lead.

It is of the utmost importance that the lead in the underground electric cables shall be protected from mechanical injury, both in the laying of the cables, and afterwards. With a good solid duct system, there is little liability to mechanical injury between the manholes, but cables are occasionally injured in the manholes by workmen repeatedly stepping upon them, or by the accidental dropping of sharp tools, which make an abrasion in the lead. After the lead has been injured in this way, the length of time that it takes for a fault to develop in a cable, depends upon the size of the cable, the voltage, the nature of the insulating material, and the amount of water adjacent to the break. If careful and systematic insulation tests are made, the fault may be discovered and located long before the cable becomes too badly grounded to use. On account of the hydroscopic nature of dry paper, a fault due to mechanical injury in a telephone cable, usually develops very rapidly.

4. Lightning.

When underground cables are connected to long aerial lines, there is danger that the insulation of the cable will be punctured by lightning, unless some efficient type of lightning arrester is placed at the terminus of the cable adjacent to the overhead lines. These lightning discharges are usually caused by static induction. The writer knows of several instances where the insulation of cables was burned out repeatedly until an efficient lightning arrester or larger ground wire was used.

5. Chemical Action.

The most danger from chemical action appears when the cable happens to come in contact with strong alkalies. I have seen samples of cable taken from a cinder-bed, in which portions of the lead were completely destroyed. The writer once located a fault in a telegraph cable of the Postal Telegraph Company, of this city. The cable had been laid across the Smithfield street bridge in a wooden box, and the electrical tests showed the fault to be at the other side of the bridge.

Upon digging up the street, and opening the box, a handful of lime was found upon the cable, and at this point the lead had been completely eaten off. The box was dry, and at other points the cable looked as new as when it had been laid. Just how the lime got there remained a mystery, but it was supposed that it had been thrown there accidentally while the cable was being placed in the box. Chemical action in creosoted wooden ducts has been known to destroy portions of the lead of the cable when not protected by the means already pointed out. In a well laid conduit system, dangers from chemical action are now considered small.

6. Electrolytic Action.

During the last few years much damage has been done to underground cables, and water and gas pipes, through electrolytic action from the currents of electric railroads. A number of cables in Brooklyn had to be replaced on account of being destroyed by electrolysis. In this city, also, a number of cables belonging to the Telephone Company had to be abandoned from the came cause. I have also witnessed the destructive electrolytic effects upon water and gas pipes in this city. In Boston, the water pipes and gas pipes were destroyed to quite an alarming extent. Many experiments have been made in order to determine methods of preventing cables and pipes from being destroyed by electrolytic action, and numerous suggestions have been made. So long as the cables or pipes are negative to the earth, there is no danger from electrolysis, and, therefore, the object to be obtained is to prevent any current from flowing from the cables to the ground. For this reason, the trolley is connected to the positive side of the dynamo, and the ground, or return feeder, to the negative. Now if the lead of the cable near the power-house is metallically connected to the return feeders or to the negative side of the dynamo, most of the current that the cable may be carrying will go directly by metallic circuit to the negative side of the dynamo, instead of passing from the cables through a

moist medium to the return feeder, and thence to the dynamo. Hence this plan of connecting the lead of the cables to the negative side of the dynamo very much reduces the possibility of destructive electrolytic action. Two other plans have been recommended, one of which is to have the negative side of one dynamo connected with the cables, the negative sides of the other dynamo being connected to the return rail feeder, and the positive side of all the dynamos to the trolley. The voltage of the one dynamo which is connected to the cable is always kept from 10 to 20 volts higher than that of the other dynamos, the theory being that by so doing, the cables will always be positive to the earth. The second plan, which applies probably more specially to water pipes, is to run insulated wires from the negative side of the dynamo, and connect them to the cables or pipes at points where tests indicate the danger of electrolysis. I have on the table some samples of lead which have been badly eaten by electrolytic action, and which were kindly loaned me by Mr. Geo. S. Bliss, of the Telephone Company.

TESTING OF CABLES.

The treatment of the subject of cables before a body of Engineers would certainly be incomplete without some reference to the ordinary methods adopted in testing cables. I have already spoken of the effects of current and voltage upon insulated wires and cables, and it now remains for me to speak of the resistance of conductors and non-conductors to the passage of the electric current.

Electric current is measured in amperes.

Electric pressure is measured in volts, and

Resistance is measured in ohms,

and the three are related by the well-known equation—

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}$$

The first two are measured for the most part by direct reading instruments, some types of which I have here on the

table, but we use an instrument called a Wheatestones Bridge for measuring the resistance of conductors, and a Galvanometer for non-conductors.

In order that you may fully understand the common methods used in locating faults it will be necessary for me to speak of the law upon which the Wheatestones Bridge is based. Fig. 2 represents the typical Wheatestones Bridge. E is the electric battery, G the galvanometer, A B and D are known resistances, and C the resistance to be determined. When these four resistances are so proportioned that no current flows through the galvanometer (G) then they are related by the following law :

$$C = \frac{A}{B} D.$$

This is Wheatestones law, and it is the fundamental principle of his Bridge or balance, as it was less commonly, but more properly, called. A and B can commonly be given the independent values—10—100—and 1,000 ohms, and D can be varied by steps of one ohm, from 0 to 11,000 ohms, so the range of the instrument is from .01 ohm to 1,100,000 ohms. This apparatus serves, therefore, as a most efficient means of determining the resistance of wires and conductors in general. When, however, we have to determine the resistance of non conductors or dielectrics, a more sensitive instrument is used, and a different method is adopted. We speak of the insulation resistance of non conductors, and 1,000,000 ohms or one megohm is the unit of insulation resistance. The Thompson Reflecting galvanometer, and the D'Arsonval galvanometer are instruments most commonly used in this work. The Thompson reflecting galvanometer consists of coils of wire in which are suspended by a fine fibre, several magnetic needles attached to a light bar. In the center of this bar is placed a fine circular mirror. By means of a lamp and a suitable arrangement of lenses, a beam of light is reflected to the galvanometer mirror, and thence to a horizontal scale divided into several

hundred fine divisions. A turning movement of the galvanometer needle caused by the passage of a current through the coil, makes the spot of light travel along the scale, and the number of divisions it goes is a measure of the amount of current flowing. The D'Arsonval galvanometer has a suspended coil and mirror, and a fixed magnet, and is used like the Thompson galvanometer. It is not affected by magnetic disturbances, and hence is a more useful instrument in practical work than the Thompson galvanometer. One of these instruments will indicate the $\frac{1}{1,000,000,000}$ th part of the current of an ordinary cell battery.

Fig. 1 gives the arrangement of the apparatus, and illustrates the method most frequently used to determine the insulation resistance of cables. The switch A serves as a means of making connections either to the cable or to a standard resistance box R. In practice, the resistance of R is either 1-10 megohm, or 1 megohm. G is the galvanometer; S the shunt; B the battery and C the cable. The shunt consists of three coils, the resistance of which bears such relation to the resistance of the galvanometer coils, that a definite and larger part of the current, flowing goes through the shunt, and the rest through the galvanometer. Plugs are used to make contact to whichever coil is desired, and in practice, the coils are so proportioned that respectively 1-10, 1-100 and 1-1000 part of the total current flows through the galvanometer. This gives a wide range of usefulness to the galvanometer, and it serves as a means of comparing accurately an insulation resistance of several thousand megohms with the standard resistance box. With the above explanation, figure 1 can easily be understood. The current from the positive side of the battery goes to the conductor E, thence through the insulation of the cable to the lead; thence from D to the shunt and galvanometer, and back to the negative side of the battery. The observer notes the deflection imparted to the needle.

Previous to doing this, however, the switch is placed in the dotted position, so that the battery current goes through the resistance box, and that shunt coil is used, which gives the largest readable deflection.

Letting M equal the multiplying power of the shunt used.

Letting R equal the resistance of resistance box.

Letting D equal the galvanometer deflection due to resistance box.

Letting d equal the galvanometer deflection due to the cable.

Then the insulation resistance of the cable $= \frac{D \times M \times R}{d}$

The resistance of most conductors increases and decreases respectively as the temperature rises and falls. The reverse is true of non-conductors. The resistance of copper changes about 1 per cent. for every 5 degrees Fahr. The change of resistance due to temperature of non-conductors is much more marked than that of conductors, and the variation is generally greater as the temperature rises. A substance which has an insulation resistance of several thousand megohms at 70 degrees Fahr. may only have two or three megohms at 150 degrees Fahr.

It often becomes necessary to determine the electrostatic capacity of a cable. We mean by electrostatic capacity the quantity of electricity that is held between one conductor and the others connected to the lead of the cable. Tests of this nature are most frequently used in connection with telephone cables, where specifications generally call for a very low capacity. The capacity of the Atlantic cables has also to be determined very carefully as upon it depends some of the methods for locating faults. Figure 3 illustrates the usual method of making tests of electrostatic capacity. B is the battery, S is the switch to make connection either to the conductor of the cable D, or to one side of the condenser L. G is the galvanometer, C the lead of the cable ; K is a key permanently con-

nected at 3, and having contact points at figures 1 and 2. When the key is pressed down so as to make contact at 1, connection is made between one side of the battery and the lead of the cable, and one side of the condenser, the other side of the battery being connected to the conductor of the cable, or to the other side of the condenser, as is desired by the switch S. The condenser is simply a modified form of the Leyden jar, and consists of alternate layers of mica or paraffined paper, and tin foil. It stands in the same relation to capacity tests that the resistance box does to insulation resistance measurements.

The better forms of condensers have a range of from .01 microfarad to 1 microfarad electrostatic capacity. When the key K is pressed down, the cable becomes charged from the electric battery, and when released, contact is made between it and 2, when the charge passes from the cable through the galvanometer G, and manifests itself by giving a sudden impulse to the galvanometer needle, the amount of which is proportional to the capacity of the cable, hence, it is only necessary to know through how many divisions the spot of light moves, for a known condenser capacity, and also how much it moves when connection is made to the cable in order to calculate the capacity of the cable.

Letting T=the needle deflection when connection is made to the cable.

Letting T′=the needle reflection when connection is made to the condenser.

Letting C=the electrostatic capacity of the condenser.

Then the capacity of the cable$=\dfrac{T \times C}{T'}$ and the capacity per mile of cable is found by dividing the above by the length of the cable in miles. Most telephone cable specifications call for this to be .08 microfarad per mile.

The electrostatic capacity of cables increases and decreases respectively with the rise and fall of temperature, and some of the laws giving the variation in this respect are extremely in-

teresting, but I will not have time now to enter fully into this subject. In many cases the variation in capacity is a logarithmic function of the temperature, but in no case that I know of is this true through a very large range of temperature. This law, however, can often be used throughout the variation of temperature which is usually met with in practice.

I fully intended to speak at length upon the subject of locating faults, but owing to the lateness of the hour, I will only be able to make a few casual remarks. The common method of locating grounds (called the Varley loop method) is simply a modification of the Wheatestones Bridge. The instruments are set up at one end of the cable, and two wires run from the Wheatestones Bridge, one of which is connected to the bad wire, and the other to a good wire. This good wire and the bad one are connected together at the far end of the cable. The resistance of the good and bad wire is then determined by the Wheatestones Bridge, after which the side of the battery which goes to the variable resistance part of the Wheatestones Bridge, is connected to ground, and plugs are removed till the galvanometer indicates a balance. The current from the side of the battery which is grounded, divides at the fault, part of it coming directly to the Wheatestones Bridge through the bad wire, the other going around by the other end of the cable, and back by the good wire to the Wheatestones Bridge. From the law of the Wheatestones Bridge, and known resistance of the good and bad wire, a formula can easily be worked out by which the resistance to the fault can be calculated. Then the resistance to the fault, divided by the total resistance of the faulty wire, and multiplied by the length of the cable, gives the distance to the fault. This is very briefly and imperfectly stated, as often numerous corrections have to be made, but the subject is aptly treated in Kempe's book of Electrical Testing, to which I refer those who care to go more fully into the subject.

DISCUSSION.

Mr. Bole:—I would like to know how a particular wire is identified in a cable having a hundred or more conductors.

Mr. Fisher:—It may be done in several ways. At one end of the cable, the particular wire sought for is connected through a battery to ground; then at the other end of the cable, each wire in turn is connected to one side of a testing apparatus, consisting of an electric bell or telephone, the other side being grounded; a signal from the bell or telephone is an indication that the sought for wire has been found. Communication between both parties at the respective ends of the cable is established by means of the telephone.

Mr. Bliss:—I have been very much interested in electrolytic action on the underground cables, having made a number of electrical tests with reference to it, in this and other cities. In one place that I have in mind, I obtained a difference of potential of 11 volts between the underground cables and the track of the electric railroad, the cable being positive with reference to the track, and it was destroyed at this place three times. Another cable had to be repaired for damages caused by electrolysis at a point at least one-quarter of a mile from the electric railway. Along one of the streets of Pittsburg I obtained a difference of potential of two to three volts between the hydrants and the track, the former being positive to the latter. This is an indication that the water pipes in that district are being injured by electrolysis.

A Member:—Have any water or gas pipes been destroyed by electrolytic action in this city?

Mr. Fisher:—I have seen several pipes taken out of the ground in the heart of the city, which were very badly corroded, but whether they were eaten from electrical or chemical action, I could not exactly determine. However, I know positively that some pipes were destroyed by electric currents near the juncture of Center Ave. and Neville St. several years ago, and some electric cables were also destroyed in that

neighborhood at the same time. The principle reason for this was that some of the ground feeders of the electric railroad were connected to the overhead return wires at that point.

MR. BLISS:—I might state here that one reason why we have not heard more of the damage done to water and gas pipes is probably due to the fact that the repairs of these pipes are generally made by laborers who would simply report that the pipe was rusted through, and hence often the real cause of trouble is lost sight of, and no electrical tests are made to determine whether or not the action was chemical or electrical.

MR. FISHER:—It is harder to prevent water pipes from being destroyed by electrolysis than cables, on account of the joints not always making good electrical contact between the adjacent sections and hence electrolytic action is set up, which eats away the pipe at the joint.

A MEMBER:—What was the cause of the failure of the first Atlantic cable?

MR. FISHER:—It was due to the fact that the cable was not strong enough mechanically, for when attempts were made to grapple for it in order to make repairs, the cable broke of its own weight. In recent years cables in certain harbors and shallow waters have been destroyed by the Teredo, a little sea animal which eats its way through the gutta percha of the cable.

There being no further discussion the meeting adjourned at 10 P. M.

DANIEL CARHART,
Secretary.

NOTE.—*The first report in response to the inquiry sent out last spring by the Chemical Section upon the Analysis of Ores and Furnace Products has now been published.*

As the subject matter is mainly of interest to chemists it has been deemed best to send the report to the members of the Chemical Section only.

But a report will be sent to any member who applies for it.

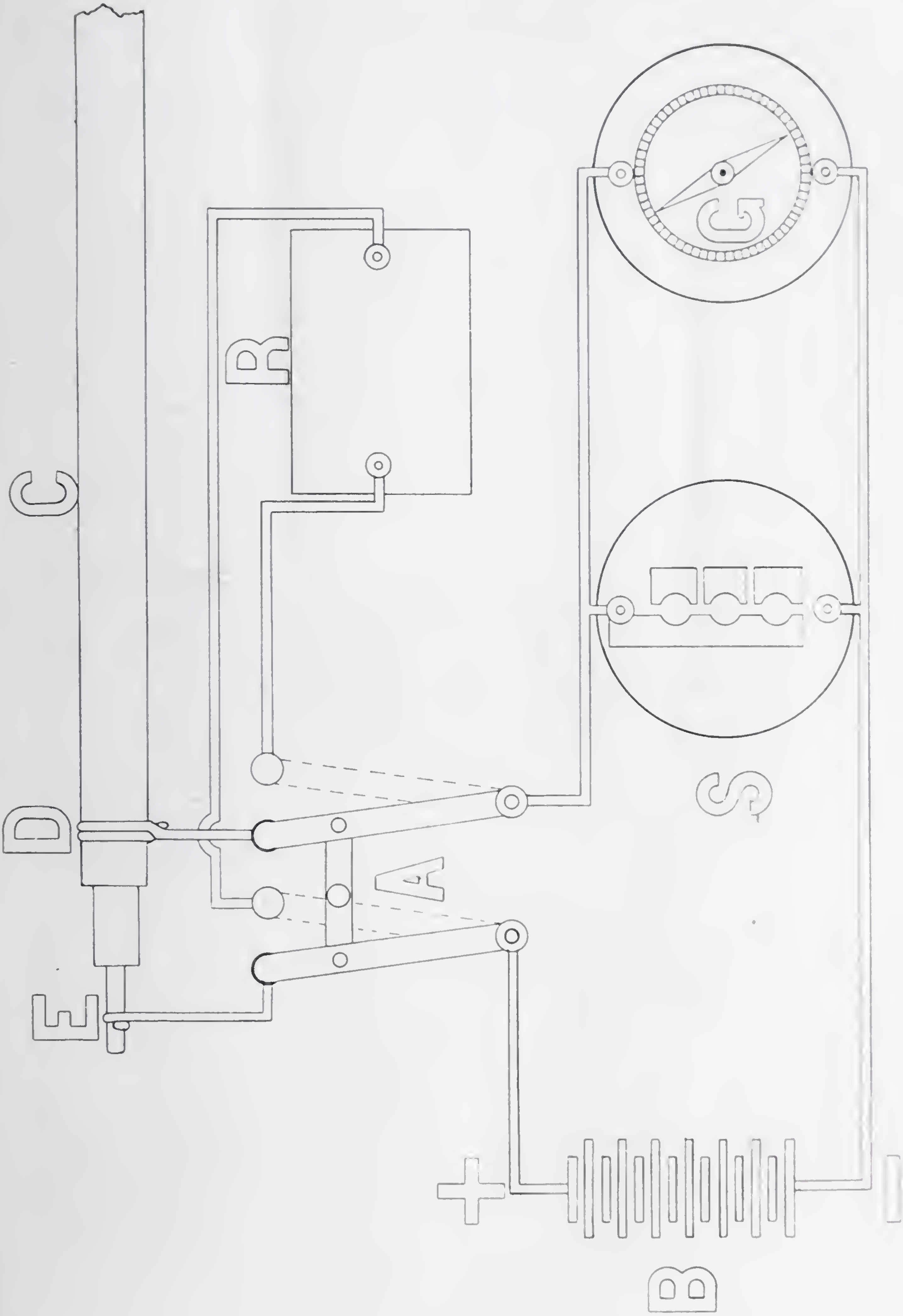

Fig. 1.

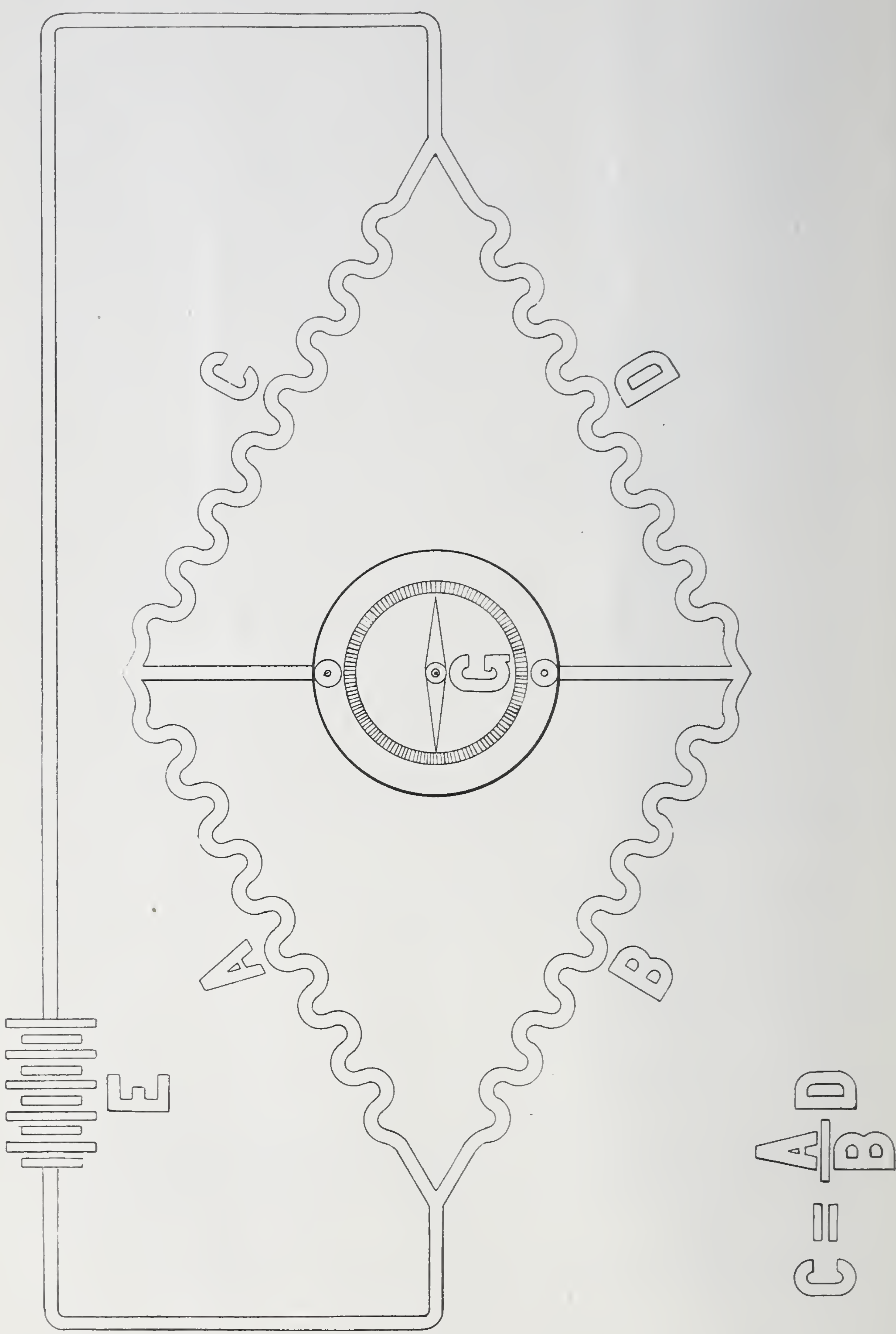

Fig. 2.

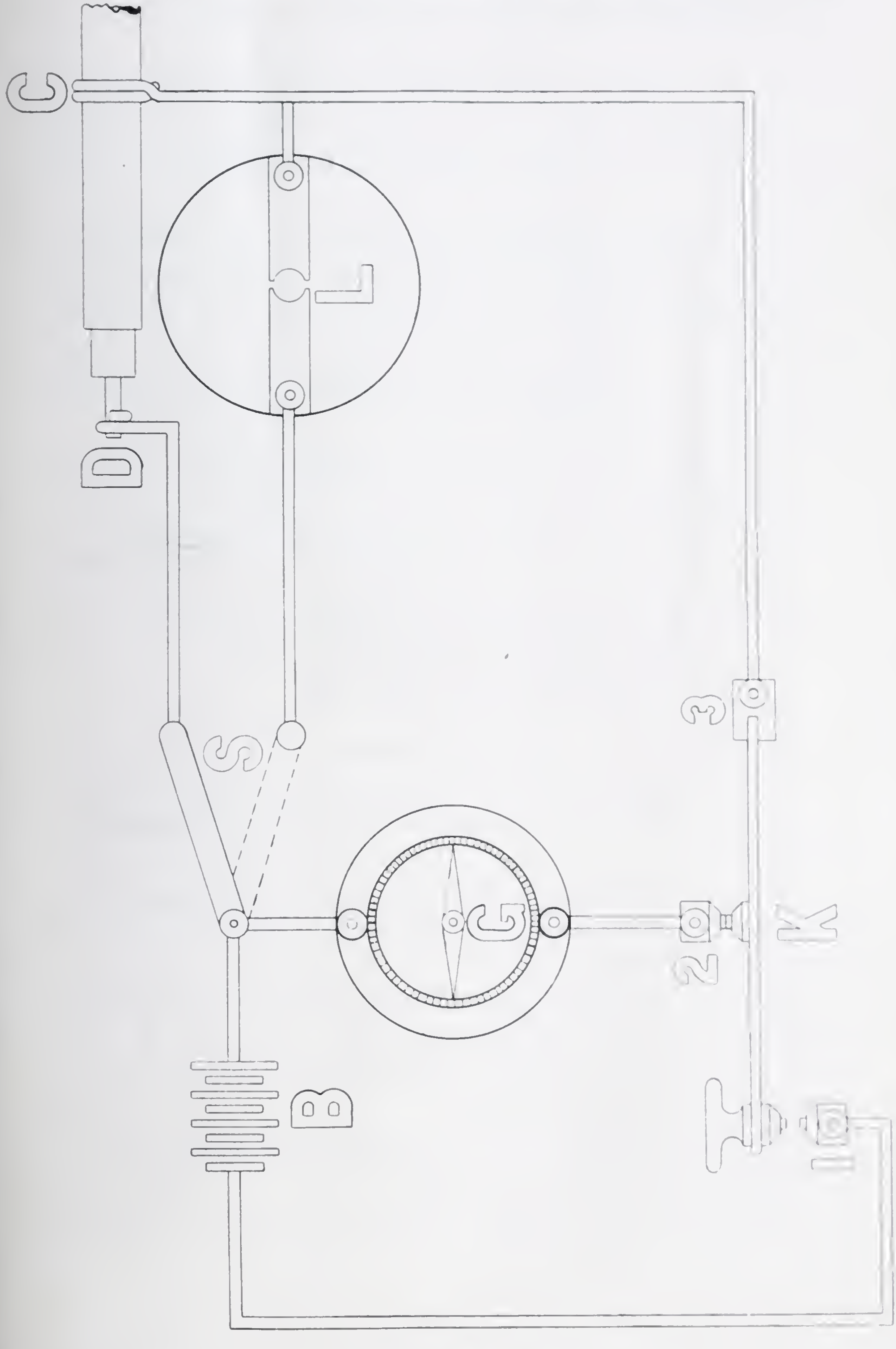

Fig. 8.

MEETING OF THE CHEMICAL SECTION.

ALLEGHENY, PA., Nov. 15, 1895.

The regular meeting of the Chemical Section was held in the lecture room of the Carnegie Library Building, on the above date.

The meeting was called to order at 8.10, by Chairman J. M. Camp ; ten members and three visitors being present.

The minutes of the last regular meeting were read and approved.

Prof. F. C. Phillips, for Committee on Methods, reported replies from the following chemists :

J. C. Barrett, Ohio Steel Co., Youngstown, O.
John Unger, Homestead Steel Works, City.
J. P. McKelvy, McIntosh, Hemphill & Co., City.
G. H. Singer, Singer, Nimick & Co., "
Fred Crabtree, Monongahela Furnace, "
C. W. Bader, Wayne Iron & Steel Co., "
S. M. Rodgers, Hainsworth Steel Co., "
R. G. Johnston, Edith Furnace, "
F. W. Brinker, Isabella Furnaces, "
A. B. Harrison, Clinton Furnaces, "
Jos. M. Wilson, Junction & Laughlin Steel Co., Mingo Junction, O.

Dr. C. B. Dudley, Chemist Pennsylvania Railroad, gave the Committee permission to publish any or all of the methods being issued by the P. R. R.

After some discussion it was decided to commence the publication of these reports at an early date, and an effort made to secure more replies to the circular letter sent out by the Committee some months ago.

Mr. A. G. McKenna, for Committee on Chemical Literature, reported the following articles :

"Report of Committee on Atomic Weights," *Chemical News*, Oct. 11, 1895, p. 180.

"Separation of Arsenic from Other Elements." *Chemical News*, Oct. 18, 1895, p. 190.

"Determination of Carbon Di-oxide Elements." *Chemical News*, Oct. 18, 1895, p. 194.

"Determination of Graphite in Pig Iron," *Journal American Chemical Society*, Nov., 1895, p. 873.

"Volumetric Determination of Titanic Acid and Iron in Ores," *Journal American Chemical Society*, Nov., 1895, p. 878.

"The Evolution Method for the Determination of Sulphur in White Cast Iron," by F. C. Phillips, *Journal American Chemical Society*, Nov., 1895, p. 895.

A communication from Jos. M. Wilson, Steubenville, O., on Loed's Sulphur Method, was read by title and referred to Committee on Methods.

Mr. Robt. Linton, of the E. Schmertz Glass Company, read the following paper:

A CALCULATION OF THE PERCENTAGE OF HEAT ACTUALLY UTILIZED IN GLASS MELTING FURNACES.

The aim of the engineer in studying the construction and improvement of furnaces for metallurgical operations is, or should be, two-fold. Superiority of product and economy of production are the points ever held in view. Of late years the latter point has received especial attention and among new inventions and improvements along this line the great majority are such as lay claim to economy in operation. Increased keenness of competition make it imperative not only that the manufacturer place a superior article on the market but that he manufacture it economically, if he is to keep up with the procession.

In the line of glass-house engineering much progress has been made within the past few years. The introduction of the continuous tank furnace is revolutionizing the manufacture of bottle and window glass so that the days of the old pot furnace

are numbered; already in Europe its use except for special kinds of glass has been practically discontinued for making these lines of glass, and this is because the tank makes as good glass as the pot furnace at greatly reduced cost. With the idea of economy so prominent in the construction of our furnaces, it becomes of interest to us to know just how economical they are and to figure out what percentage of the heat developed in the combustion of the fuel is actually absorbed in melting our raw materials into glass.

There is such a variety of kinds of glass and so many special forms of furnaces in use that it would be a tedious task to make calculations that would cover all of them. Since it is customary to regard a soda-lime glass as the most representative kind, and since it comprises the bulk of the glass manufactured, we will use it for our calculations, and confine them to such furnaces as melt it, viz: furnaces for plate, window and bottle glass. The most of this glass will approximate the composition represented by the formula:

$$CaO\ Na_2O\ 5SiO^2.$$

The raw materials are sand, carbonate of lime, carbonate or sulphate of soda and carbon. The chemical process is the change from the carbonates and sulphates to the silicates of the same bases, which takes place in fusion at high temperatures. The problem of melting glass is a problem of the proper application of heat to the batch, as the mixture of raw materials is called. In melting it there is a considerable diminution in bulk and weight, so that when it is melted in a pot the filling of batch must be repeated several times before the pot is filled with the molten glass. The batch will lose nearly one-fourth of its weight and about three-fourths in bulk in the part of the melt which is represented by the chemical changes indicated above. When, however, the batch is merely melted down to this point it is not yet glass in a technical sense, although it is a mixture of silicates and thus glass in a chemical sense. The carbon and sulphurous fumes liberated by the reaction, steam

that comes from moist materials and air held in suspense in the powdered batch fill the molten mass with bubbles of gas that are prevented from escaping by the stiffness of the glass. If we should attempt to work it at this stage, we would find it a lumpy, seedy, stringy mass that would scarcely hang together. In order to free the glass from this gas held in suspense and mix it at the same time thoroughly so that it is throughout a homogeneous mixture of silicates it is heated until it is soft enough to allow the bubbles to rise, and agitated repeatedly by stirring it. In this way it is cleared and becomes the limpidly transparent glass of commercial value. Before being worked however, it must be allowed to cool and stiffen somewhat. A melt therefore, whether made in a pot furnace or a continuous tank furnace is divided into three periods: the melting down, the clearing or fining, and the cooling or standing off. The first two of these absorb heat. The last gives off heat.

As to furnaces there are, as already indicated, two systems in use—the pot furnace or intermittent, and the tank furnace or continuous system. In the pot furnace the batch is filled into pots holding about three-fourths of a ton of melted glass, a furnace having ordinarily eight or ten pots. The batch is filled in, melted and then worked out, but as it takes about twice as long to make a melt as it does to work out the glass the blowers can work only about one-third of the time. Great care must be taken with the pots as a broken pot means lost glass and lost work. The tank furnace is constructed on an entirely different plan. It is an oblong reservoir always kept filled with melted glass. The batch is filled in at one end and floats gradually down to the other, melting and clearing as it goes, and when it reaches the other end where it is worked out it is pure glass. The dimensions of tank furnaces vary greatly. In general window glass tanks are long and narrow, while bottle tanks are short and wide, if a fusible batch is used, or more nearly of the shape of window glass tanks if the batch is less fusible. European bottle tanks are as a rule horsesho

shaped, fired either across or from behind by making the flame describe a semicircular path. Some few are even circular in shape. The fusibility of the batch has much to do with the construction of tanks, and as there is such a variance in the fusibility of bottle glass mixes we find a corresponding diversity in the construction of bottle tanks, while the general outlines of window glass tanks are the same wherever they may be found, since window glass is made from practically the same batch everywhere. Of these two systems of melting furnaces the economy of the tank over the pot furnace in fuel and labor will be apparent. The increased actual utilization of fuel will be found to be considerable.

In the following calculations the thermo-chemical data are obtained from Dr. Alex. Naumann's Handbuch der Thermochemie, and for the sake of convenience the metric system is used. We will first determine the amount of heat necessary to melt a kilogramm of glass, and the amount of heat developed by the combustion of a kilogramm of coal in a gas fired furnace, for glass making of the present has to do only with such. We will assume a glass of the composition

SiO_2	72.1
CaO	13.6
Na_2O	14.5
	100.2

the glass being made of a melt of sand, limestone, sulphate of soda and carbon. To melt a kilogramm of glass we will have to use,

Sand,	.721	kg.
Limestone,	.243	"
Sulphate of soda,	.332	"
Carbon,	.022	"

1 kilogramm glass to melt and raise to the melting temperature of a furnace, Ackerman,	490	Cal.
.332 kilogramm Na_2SO_4 to decompose by reduction, $.332 \times 380 = 126$; $.022 \times 2400 = 53$ reaction of C to CO,	73	"
.243 kilogramm $CaCO_3$, to decompose; $.243 \times 425 =$	103	"
	666	"

The clearing up process must also be taken into account since it is a heating process. If we knew just the temperature at which the chemical reaction is completed and then ascertain how much above this the glass must be heated, we could tell this with accuracy. Lacking this information we will get at the same thing approximately from furnace practice. It will take about 40 per cent. of the amount of fuel required to melt glass to clear it up. Applying this to the above, i. e., adding 40 per cent. to it, we will have for the entire melt 932 calories necessary.

Our fuel we will take to be a bituminous gas coal such as is commonly used in this vicinity, having about the composition,

Fixed carbon,	67
Hydrocarbons,	31
Ash,	2
	100

If this is made into gas in an ordinary steam blast producer, good practice will utilize about 64 of the carbon and about 25 of the hydro carbons in the above, and of the 64 parts of carbon, about 55 would burn to CO and the balance to CO_2. 1 kilogramm of coal would then give the following gas :

.55	kg.	C with .7333 kg. O	give	1.2833	kg.	CO
.09	"	C " .24 " "	"	.3300	"	CO_2
.25	"	HC	"	.2500	"	HC
.2433	"	O in HO	"	.0304	"	H
.73	"	O in Air	"	2.5560	"	N

This will give a gas of the following composition by volume :

CO_2	4.3
CO	26.4
HC	8.9
H	8.6
N	51.8
	100.0

1.2833×2431	gives	3120 Cal.
$.25 \times 13000$	"	3250 "
$.0304 \times 33800$	"	1027 "
Total		7397 "

The total amount of heat potentiality of the coal is :

$.67 \times 8080$	gives	5414 Cal.
$.31 \times 13000$	"	4030 "
		9444

The efficiency of the gas is therefore 78 per cent.

To apply the above we have the following figures, which may be taken as average practice :

1 kg. coal will melt .45 kg. glass in a pot furnace.

1 kg. coal will melt 1 kg. glass in a window glass tank.

1 kg. coal will melt 1.75 kg. glass in a bottle tank.

$.45 \times 932$ gives 419 Cal.

$\frac{419}{7397}$ gives 5.7 per cent. efficiency of pot furnace.

$\frac{932}{7397}$ gives 12.6 per cent. efficiency of window glass.

932×1.75 gives 1631 Cal.

$\frac{1631}{7397}$ gives 22 per cent. efficiency of bottle tank.

The above are calculated from the heat potentiality of the gas as it comes to the furnace. If we base the calculation on the heat potentiality of the coal itself, then the efficiency of the above styles of furnaces will be 4.4, 9.8 and 17.2 per cent. respectively.

In making plate glass the alkali is usually furnished by carbonate of soda instead of sulphate of soda, as above. In composition the glass does not vary greatly from window glass, and the furnaces in which it is made resemble a pot furnace for window glass, in general outlines, though the pots do not stand as close to the breast wall of the furnace and consequently are better exposed to the action of the heat. We will take a glass of the following composition:

SiO_2	72.
CaO	13.
Na_2O	16.

For one kilogramm of glass we will have to melt:

Sand - -	.72 kg.
Carbonate of lime	.232 kg.
Carbonate of soda	.257 kg.

The amount of heat necessary to melt this will be:

1 kg. glass to melt and raise to the melting temperature of the furnace - -	490 Cal.
.232 kg. limestone to decompose, $.232 \times 425$	99 Cal.
.257 kg. carbonate of soda to decompose, $.257 \times 711$ - - - - -	182 Cal.
	771 Cal.

40 per cent. added to 771 Cal. gives 1079 Cal., the total heat required to make 1 kg. glass.

We will take natural gas as the fuel in this case, and it will take about 4.3 cubic meters, or .844 kg. gas for 1 kg. of glass. Prof. F. C. Phillips has found natural gas to be composed of about 90 per cent. paraffins, therefore .844 kg. of natural gas will contain .76 kg. paraffins, which will develope in combustion 9880 Cal.

$\frac{1079}{9880}$ gives 10.9 per cent. efficiency of plate glass furnace fired with natural gas. A coal fired furnace would not show as high a percentage.

We see therefore that there is quite a difference in the efficiency of different forms of melting furnaces. It is gratifying to note that the modern furnaces show an efficiency so much higher than those of less recent construction, and we may hope that further improvements may bring about the construction of furnaces in which the waste of heat may be still further reduced.

After some general discussion the meeting adjourned at 9.45 P. M.

A. D. WILKINS,
Secretary C. S.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

ALLEGHENY, PA., Dec. 19th, 1895.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, Dec. 19, 1895.

The meeting was called to order at 8.30 P. M.; Mr. Thomas H. Johnson, President, in the Chair, and 50 members and visitors present.

The minutes of the last meeting were read and approved.

The following applicants for membership were by ballot unanimously elected members of the Society: S. A. Benner, F. F. Fischer, G. E. Klingelhofer, S. V. Huber and A. K. Ashworth.

The Reception Committee reported that they were arranging for a banquet to take place Jan. 30, 1896. Moved and seconded that the report be accepted. Carried.

The Room Committee reported progress.

The Committee on Nominations presented the following report, which was duly received:

MR. PRESIDENT AND MEMBERS OF THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA:

Your committee appointed at the regular meeting of the Society, held on the 21st of November, 1895, for the purpose of nominating officers for the ensuing year, report as follows:

For President, to serve one year, W. G. Wilkins;
" Vice-President, to serve two years, G. S. Davison;
" Directors, to serve two years, W. A. Bole and Franz Engstrom;

" Secretary, to serve one year, D. Carhart;
" Treasurer, to serve one year, A. E. Frost.

Nominating Committee,

Per EMIL SWENSSON, Chairman.

ALLEGHENY, December 19th, 1895.

For members of the Auditing Committee, the President appointed Messrs. Schluederberg, Chas. Davis and W. A. Bole.

Mr. L. B. Stillwell then read his paper entitled: "Possibilities of Electrical Transmission and Distribution of Power in Pittsburg."

POSSIBILITIES OF ELECTRICAL TRANSMISSION AND DISTRIBUTION OF POWER IN PITTSBURG.

I presume no member of the Engineers' Society of Western Pennsylvania will question the following assertions:

1. Pittsburg is an exceptionally smoky city.
2. The smoke is largely due to imperfect combustion in fires kindled under boilers for the purpose of producing power.
3. Electricity is an extremely efficient and convenient means of distributing power from a central station.

There is a fourth proposition which I should like to advance, viz.: The annual depreciation of property, and especially of household furniture, clothing, etc., in and around Pittsburg represents a sum of money more than equal to the value of the coal burned to produce the power that we use.

The truth of this fourth statement I am not now prepared to demonstrate, nor is it essential to the consideration of the subject which I have selected; nevertheless I believe it to be a true statement, and it will be useful in assisting us to place certain facts and suggestions, to which I invite your attention, in proper relation and perspective.

If a member of this society were to go up in a balloon one of these dark mornings he would doubtless be astonished to find the sun shining brightly not more than half a mile above the two cities. He would see Pittsburg simply as a

black spot upon the face of the earth. It is a pity that we cannot all go up in balloons, for it is possible that much good might result from a thorough understanding and appreciation upon the part of the members of this society of the fact that the sun does shine and that we are existing under atmospheric conditions (not to mention other conditions) which in this day of boasted science are little short of disgraceful.

This may seem to be a strong statement, but permit me for a moment to postpone the inevitable assumptions and interminable calculations of the usual paper upon an engineering subject, and endeavor to place before you an accurate view of the general situation before presenting briefly the results of some study upon a possible method of attaining better things.

Let us suppose for a moment that a select committee of this society is securely suspended in the basket of a huge balloon half a mile above the site of old Fort Pitt. Let us assume further that this committee is in possession of a file of the proceedings of this society for the year 1894, and that while enjoying themselves in the unwonted sunlight they glance over the reports with a view to finding out what causes all the smoke, how the leading engineers of this part of the State explain its presence and what steps they are taking for its elimination. What would our committee learn?

They would read in Mr. Chas. F. Scott's very able paper printed in the proceedings for February, 1894, that of the total energy in the coal which those little people down there are so busy digging and burning, less than 7 per cent. is delivered at the shafts of their engines, and that there are several ways to transmit power by electricity over very considerable distances. They would read in the interesting paper of Mr. C. M. Taylor, printed in the September number of the proceedings, that while, up to about ten or fifteen years ago, a very large proportion of the coal in the hills was wasted by injudicious systems of mining, about 85 per cent. is now actually shipped—a very gratifying result and one that undoubtedly

shows good progress in an important field of practical engineering. They would learn from the valuable papers of Mr. G. E. Tener and Mr. Wm. White, Jr., upon the respective subjects "Lake Shipments and Handling of Lake Coal" and "Weathering of Fuel," printed in the October number of the proceedings, that a very considerable amount of coal is depreciated in value before it is burned, by breakage in handling and by weathering, against both of which sources of loss the best attention and skill of those immediately concerned appear to be directed. They would read in Mr. Ashworth's paper in the November number of the proceedings a great many explanations of the poor average economy obtained in the use of fuel, and they would find out what causes a very large proportion of the smoke; that one way to improve practice is to induce owners to be watchful and to educate firemen, but that owners are rarely watchful and firemen refuse to be educated. And lastly, they would learn from the excellent paper of Mr. Wm. A. Bole, printed in the December number of the proceedings, that no steam engine converts into useful work more than one-sixth of the energy of the steam delivered to it from the boiler, that there are very great differences among engines as regards their efficiency, some developing under test one h. p. hour for about 14 pounds of steam, while others require as much as 100 pounds of steam to accomplish the same result.

What do you suppose our committee would conclude, enjoyng keenly rays of pure sunlight such as never before fell upon a Pittsburg committee, realizing that beneath that black canopy nearly half a million of people are working, striving, choking, enduring, and assured by the testimony of the proceedings of the foremost engineering society of Western Pennsylvania that the smoke is largely due to fires badly managed? Would they not resolve that something must be done at once to remove the smoke and dirt, by improving the methods of developing power for industrial purposes? And knowing, as of course, being members of this society they must know, that in a large

steam plant properly installed and well managed, smoke can be eliminated; that there are such things as electric generators and electric motors; that if a copper wire arranged in a long loop, supported upon glass or porcelain, or encased in rubber, be connected in a certain way to a generator at one place and a motor at another, we may build our fire here and do work over yonder, even at a distance of many miles: would they not decide that no small power plants producing smoke ought to be tolerated and that every wheel of industry in Pittsburg and Allegheny ought to be turned by energy developed in a central station, where the production of smoke could be absolutely avoided? And in arriving at this conclusion, having the large facts of the situation arranged in proper perspective, I do not think they would be inclined to take the usual narrow view of the so-called practical man and the narrow gauge engineer, and declare that unless the advocates of any proposed change of methods can demonstrate beyond the possibility of a doubt that it will directly and immediately save money for those using the power, their plans should not be considered. They would perhaps be inclined to regard to some extent the natural right of man to a share of pure air and sunshine, and might even be disposed to believe that a man does not necessarily possess the right to impose soot and smoke upon his neighbors simply because it has been his habit to do so.

But, leaving our committee, permit me to reverse the usual order and arrangement of a properly constructed paper which aims to give the results of a series of calculations, and state my general conclusion at the outstart in order that you may know at once what I believe the calculations indicate, and so may the more carefully and critically observe the assumptions upon which they are based and detect any lapse in the reasoning. That conclusion may be stated as follows:

In the central wards of Allegheny and Pittsburg a marked saving for the users of power in the case of all but very large steam plants, would result from the substitution of electric

motors supplied with energy from a 20,000 h. p. central station properly designed and installed.

This opinion has not been taken as a starting point in the preparation of this paper, but has been arrived at as a conclusion, based upon which I believe to be a fair, and in general accurate, although in some respects necessarily incomplete, study of the subject.

At first glance it may seem that electrical transmission of power to Pittsburg is like "the carrying of coals to New Castle," but if my assumptions and calculations are correct the project is from an engineering standpoint both feasible and economical. I have made some calculations of the cost of power distributed by electric motors and conductors from a steam plant capable of delivering to the shafts of electric generators 20,000 h. p. Two different locations of the steam plant are assumed and the calculations in each case carried out for the purposes of comparison. In estimating the cost of steam plant I have closely followed the calculations of Dr. Chas. E. Emery, as recorded in his second paper on "Cost of Steam Power," read before the American Institute of Electrical Engineers at its twelfth general meeting, June 26th, 1895. That paper was read at Niagara Falls, and it was obviously Dr. Emery's purpose to compare the results of the best steam practice in a plant developing 20,000 h. p. with the cost of electric power as developed in the hydro-electric plant at Niagara. Assumptions not found in Dr. Emery's paper and modifications of his estimates where such have been considered advisable, will be stated.

FIRST PLAN.

Central Station located at an average distance of ten miles from four sub-stations in Pittsburg and Allegheny.

In those calculations of Dr. Emery, which most nearly approximate probable conditions as to variation in load which would govern, he makes the following assumptions :

1. Coal costs $2.24 per long ton (2240 lbs).

2. Sufficient water for condensing purposes is available, and condensing engines (presumably triple expansion type) are used.

3. One indicated h. p. hour is obtained from 1.25 lbs. coal.

4. The plant develops:

20,000 h. p. ten hours per day.
12,000 h. p. ten hours per day.
5,000 h. p. four hours per day.

These conditions govern for 309 working days per year. During each of the 56 holidays 5,000 h. p. is produced for 24 hours. An amount of coal equal to average consumption for one hour during regular operation is allowed "to maintain banked fires, overcome radiation and bring the fires to average working condition, when they are again put in operation."

5. The cost of the complete steam plant, including buildings, is $64 per h. p., and one-eighth surplus power is put in the station for a reserve or relay.

6. The engine unit is 2,500 h. p., and nine engines are installed.

7. The cost of steam plant complete is $1,440,000.

I have assumed that coal can be delivered to boilers for $1 per long ton. This is probably somewhat high. With this modification, Dr. Emery's statement of the cost of power (Transactions of the American Institute of Electrical Engineers, vol. 12, page 471) is as follows:

Yearly cost of coal	$70,377
Cost of labor per year	34,512
Cost of superintendence per year	13,140
Supplies and regular repairs	73,584
Taxes, insurance and renewals	72,000
Interest	72,000
Total	$335,613

COST OF ELECTRIC GENERATING PLANT.

The general arrangement of an electric plant suitable to transmit to Pittsburg power developed by Dr. Emery's steam plant will we assume be similar to that adopted for the installation at Niagara Falls, which is described in Mr. Charles F. Scott's paper recorded in the proceedings of the society, February, 1894.

In this case the electric plant in the central station will comprise the following:

Nine direct connected 2,400 h. p. polyphase alternaters,

Raising transformers aggregating 21,200 h. p.,

Two direct connected 250 h. p. exciters,

Switchboard with equipment of switches, measuring instruments and safety devices.

The cost of this electrical plant installed is calculated from present market prices of electrical machinery to be $432,000.

The annual charges against this electric generating plant are estimated as follows:

LABOR (3 SHIFTS).

Three station engineers, at $1,800	$ 5,400
Six assistants at $900	5,400
Superintendence, say	10,000
Supplies, at 25c per h. p.	5,400
Maintenance, 3 per cent. of $432,000	12,960
Taxes and insurance, 2 per cent. of $432,000	8,640
Interest, 5 per cent.	21,600
Total	$ 69,400
Add cost of mechanical power	335,613
Total cost of electrical power delivered to transmitting circuits	$405,013

For generators of this large size an actual efficiency of 96 per cent. can be attained, and for the step-up transformers

98 per cent. is not too high. Such a plant will therefore be capable of delivering to the transmitting circuits 18,816 h. p. when the generators receive from the engines 20,000 h. p. The mean power delivered is, in line with Dr. Emery's assumptions, 12,005 h. p.

TRANSMITTING CIRCUITS.

We now come to the calculation of the conductors used for the transmitting circuit and assume the following conditions:

1. The potential employed is 10,000 volts at the secondary terminals of the step-up transformers. (This is the potential which for several years past has been successfully transmitted through underground circuits in London.)

2. Insulated cables, laid in suitable ducts underground, are used. (No overhead construction for high potential circuits passing, as these must, through thickly populated districts should be tolerated.)

3. Tri-phase circuits are adopted, and the energy of the plant is normally transmitted through two circuits, each consisting of three insulated conductors. A third circuit consisting of three insulated conductors of the same section as those regularly used is laid down for use as a relay in case of accident.

It is further assumed, from information furnished by manufacturers, that in suitable conductors having a copper section of about one-third of a square inch, the insulation will cost three times as much as the copper, and that the copper will cost 14c per pound. Upon these assumptions I find the following:

Cost of copper	$166,950
Cost of insulation	500,850
Total	$667,800

Suitable ducts would cost 10c per foot, and using three ducts, one for each of the three wire circuits, we find:

Cost of duct..........................	$ 16,900
Laying duct, drawing in and connecting cables (estimated)....................	105,900
Grand total for transmitting circuits and ducts	$790,700

Assuming that two three-wire circuits are employed to transmit the current, while one three-wire circuit is held in reserve, and assuming that since the energy is to be ultimately delivered to induction motors the current will lag behind the electro-motive force to an extent that will make the lag factor at maximum load .90, we find that the loss in the circuits at maximum load is 2,320 h. p. (a little more than 12 per cent.), but the mean loss will be considerably less than this, since the loss in circuits will vary as the square of the power transmitted. With the load line assumed by Dr. Emery, we should have in the circuits a mean loss slightly under one-half the maximum loss, i. e., the mean loss would be about 1,150 h. p.

We need this figure in calculating the proper size of the conductors for the transmitting circuits, since to secure the best economy the value of the energy lost in the circuits should equal the interest on the investment in the conductors. But it will be noted that while the mean loss is a little less than one-half the maximum loss, the cost of the mean power lost will be proportionately somewhat greater, because of the fact that the cost of the unit of power under conditions of partial load exceeds the cost of the unit of power under conditions of maximum load. For this reason I have taken the value of the mean energy lost to be .6 of the value of the maximum energy lost, and we will compare with the annual charges against the investment in the transmitting circuits the value of .6 × 2,320 h. p. = 1,392 h. p.

And now what does a mean loss of 1392 h. p.,—or practically 1400 h. p., fairly represent in money value? We have found that the load line assumed by Dr. Emery implies an average of 12,000 h. p. delivered to the transmitting circuits,

and that the annual cost of operating the steam and electric generating plant, including interest on the investment, is \$405,-000. The cost of developing the average horse-power is therefore \$33.75, and the mean value of the energy lost is $1392 \times 33.75 =$ \$46,980. The annual charges against the transmitting circuits may, I think, be fairly taken at 8 per cent.; that is 5 per cent. for interest, and 3 per cent. for maintenance; and for our present purpose we consider only the annual cost of copper and insulation, amounting to \$667,800, since the cost of ducts, and of drawing in and connecting cables will not be appreciably changed by a slight alteration in the section of the conductor. Taking 8 per cent. of \$667,800 we have \$53,424; the annual charges against the circuits are, therefore, about \$7,000 in excess of the money value of the loss due to resistance of the transmitting conductors, and it would appear that we should use a less expensive conductor. But it is sound engineering to allow a substantial margin on the safe side of calculations such as these, and while there is no doubt that \$405,000÷12,000=\$33.75, there is in my judgment room for some question as to our ability to attain this exact result in practice, chiefly for the reason that Dr. Emery has assumed that one horse-power hour may be obtained from 1.25 pounds coal, and while such a result may undoubtedly be obtained under certain conditions during a test, it is hardly possible that it can be maintained as an average during commercial operation of the plant. Let us, therefore, round out our figures and take the cost of producing an horse-power to be, say, \$40.00 instead of \$33.75. Upon this assumption we find the cost of the mean loss to be a little less than \$56,000, which compares very closely with the annual charges against the conductors. We may say, therefore, that the section chosen, (namely, one-third of a square inch of copper in each conductor,) is about right.

In this calculation it will be noted that I have compared with the annual charges against the circuit the *cost of producing*

the power lost in the conductors—not the *selling value* of that power. This is correct so long as we are able to develop, by extensions of the plant, more power than the market calls for, and while for purposes of calculation we have assumed a 20,000 h. p. plant, there is obviously no reason why the plant might not be increased to a practically indefinite extent.

LOSSES IN STEP-DOWN TRANSFORMERS, LOCAL DISTRIBUTING CIRCUITS, ETC.

The maximum power delivered at the end of the high potential transmitting circuits, which we have assumed to be 10 miles long, is, of course, found by subtracting the maximum loss in these circuits from the maximum energy delivered to them by the step-up transformers that in 2,320 from 18,816 h. p.=16,496 h. p. It will, in all probability, be found advisable to lay down branches of the transmitting circuits to convey the energy at high potential to three or four points, from which the distributing conductors, conveying the current at lower potentials, will radiate. Assume, therefore, four local distributing points. At each of these a small one-story, fire-proof structure, say 40 feet long by 20 feet wide, must be erected for the step-down transformers which reduce the potential to about 3,000 volts. At 3,000 volts a No. 0000 conductor, B. & S. gauge, will transmit 400 kw (about 530 h. p.) a distance of 1.5 miles with a loss of 3 per cent., the lag factor being .9 ; and as it would seem that a very large proportion of the motors might be reached by circuits 1.5 miles long, radiating from four suitably located sub-stations, I have assumed the loss in the local distributing circuits to be 3 per cent. It is, of course, impossible to make an exact estimate of the cost of local distributing circuits in the absence of exact information as to the location and power of the motors which would be required to do the work now done by engines, but a radius of 1.5 miles, starting from each of four properly located substations, means that the diameter of the circular district supplied from each sub-station is 3 miles, and the total area cov-

ered by the system is about 28 square miles in those parts of the two cities where power is chiefly used. The purpose of this calculation is to present a general view of the situation, and the members of this Society will, no doubt, be able to supply in the discussion, information from which these calculations of the local circuits, based upon a general assumption, can be intelligently revised, and brought into closer agreement with conditions determined by local geography and the actual locations of existing steam plants.

And now let us see what maximum energy our plant is capable of delivering to the premises of the users of power. We have found that the maximum power delivered to the step-down transformers equals 16,496 h. p., and subtracting from this 2 per cent. (equals 330 h. p.) for loss in step-down transformers, we have a maximum power delivered to circuits equals 16,166 h. p. Again subtracting 1½ per cent. (equals average loss in local distributing circuits), we have power delivered to premises of the users equals 15,924 h. p. This is the power which should be sold; that is to say, the company owning the central station plant, transmitting circuits, sub-stations with local distributing stations, should sell to the users of power, electric energy at 3,000 volts potential delivered upon the premises. The maximum power which the assumed plant is capable of thus delivering is 15,924 h. p.

Those who use the power will find it necessary to install upon their premises step-down transformers, ratio, say 3,000-200 volts and motors; the efficiency and cost of these will vary with the amount of power which they are capable of delivering, and although in one sense the proper stopping place in this calculation is where the current is delivered to the premises of the user of power, it may be interesting to go a step further and calculate the losses in the transformers and motor upon the premises of the customer. These losses should not exceed 3 per cent. in the transformers. The efficiency of the motors, as I have said, varies between wide limits, but

the efficiency of a 20 h. p. motor at full load is 85 per cent. or better, and it would seem perfectly safe to say that the average loss in motors under full load would not exceed 15 per cent. We find, therefore, that the energy actually delivered to motors is 15,446 h. p., while the aggregate mechanical power delivered at shafts of motors is 13,169 h. p.

COST OF POWER DELIVERED TO CUSTOMERS.

We have found the annual cost of delivering power to the high potential transmitting circuits to be $405,000. To this we must now add the following:

(1) Interest and maintenance for transmitting circuits, say 8 per cent. on $737,700 = $59,016.

(2) The cost of lowering transformers, aggregating 16,-166 h. p., amounts, at $5 per horse power, equals $80,830. The cost of four sub-stations will approximate $20,000. The annual charges against the step-down transformers are 5 per cent. for interest and 3 per cent. for maintenance, equals 8 per cent. on $80,830 = $6,466. Interest, taxes, insurance and maintenance of sub-stations, say 8 per cent. of $20,000 = $1,600.

(3) Ducts for local distributing circuits. I have assumed that from each sub-station four trunk lines of ducts will be laid down; that each of these trunk lines will be 1.5 miles long; that two ducts approximating 4 inches in diameter will be used; that these ducts will be laid under average conditions and at average depths similar to those which govern in the case of similar ducts now being laid in this city. The aggregate cost of 24 miles of what we may call trunk line ducts would approximate $240,000. Adding for branch ducts $60,000, we have total cost of ducts for local distribution equals $300,-000. From information kindly furnished by Mr. T. B. Hughes, of the Washburn & Moen Company, I have calculated cost of cables for local distribution upon assumptions above stated to be approximately $600,000. The annual charges against the local distributing system are therefore as follows:

Ducts: Interest 5 per cent., maintenance 1 per cent., $18,000.

Cables: Interest 5 per cent., maintenance 3 per cent., \$48,000.

The annual cost of delivering the power to the premises of the users is found by adding the annual changes under 1, 2 and 3 to the cost of the power as delivered to the high potential transmitting circuits. In this way we find that the annual cost of the power delivered to customers is \$479,079.

SECOND PLAN.

Central station located in Pittsburg, say on bank of Monongahela or Allegheny river, where coal can be cheaply delivered, and water for condensing purposes readily obtained. As compared with the first plan we avoid at once the investment in the 10,000-volt transmitting circuits. We no longer need the ducts between the generating station and the city. In place of these two items, however, we must estimate the cost of ducts and cables to convey three-fourths of the total power to the three sub-stations now remaining as distributing points. In this case the generators will be wound to deliver their currents at 3,000 volts, and no step-up transformers will be needed. The efficiency of the electrical system under this plan is as follows:

Power delivered by engines to generators	20,000 h. p.
Loss in generators, 4 per cent	800 "
Power delivered by generators to 3,000-volt circuits	19,200 h. p.

Loss in 3,000-volt transmitting circuits:

6 per cent. of 14,400 = 864 h. p.

1.5 per cent. × (19,200 — 864) = 275 h. p.

Total loss in 3,000-volt circuits = 1,139 h. p.

Power delivered to users of power.....18,061 h. p.

Under the first plan the maximum power delivered to the users is 15,924 h. p. The difference in favor of the second plan is therefore 2,137 h. p. The respective investments required under the two plans considered compare as follows:

	First Plan.	Second Plan.
Steam plant	$1,440,000	$1,440,000
Electrical generating plant	432,000	357,000
10,000-volt transmitting circuits	790,700	
3,000-volt transmitting circuits (cables)		525,000
3,000-volt transmitting circuits (ducts)		24,000
Lowering transformers	81,000	
3,000-volt distributing circuit (cables)	600,000	600,000
3,000-volt distributing circuit (ducts)	300,000	300,000
	$3,643,700	$3,246,000

The total loss in 3,000-volt circuits in the second plan, amounting to but 1,108 h. p. at maximum load, while the investment in the cables amounts to $1,125,000, it is evident that the loss assumed in these cables should be increased; that is to say, the section of the cables, or their number, should be reduced. We cannot here apply the law of maximum economy without some regard to the effect upon the regulation of the system, but we may safely double the loss in the 3,000-volt circuits, making that loss under conditions of maximum load 2,278 h. p., reducing the total power delivered to premises of the customers to 16,922 h. p., and reducing the investment in 3,000-volt conductors by $562,500. The cost of the plant under the second plan then becomes $2,684,000. Doubling the loss in 3,000-volt circuits in the case of the first plant will reduce the investment in that case to $3,364,000, which is still $680,000 above the investment required by the second plan, while the power delivered to premises of customers under the second plan still exceeds that which is delivered under the first plan by about 1,000 h. p. There is no question, therefore, that the plan of installing a power plant in the city rather

than in the immediate vicinity of the coal mines is the better one. The annual charges against this second plant as thus modified are as follows (assuming coal delivered to be $2 per long ton):

Total charges against steam plant		$406,000
Electrical plant at generating station		64,000
Sub-stations:		
Interest and maintenance	$1,600	
Attendance	5,400	
		7,000
Ducts, 6 per cent. of $324,000		19,440
Cables, interest and maintenance, 8 per cent. of $562,500		45,000
		$541,440

To sum up we may say,—adding a good margin to our figures for safety—that such a plant can be installed for a sum not exceeding $3,000,000, and that if Dr. Emery is right in his estimate of the cost of steam power, the total annual charges against such a plant, including operating expenses, maintenance, taxes, insurance and interest upon investment, should not exceed $600,000. The plant is capable of delivering at any given time to the premises of the users of power energy at 3,000-volts potential aggregating 17,000 h. p. Allowing 3 per cent. for losses in the transformers, and 15 per cent. for average losses in the motors installed by the users of power, the plant would be capable of developing at the shafts of these motors quite 14,000 h. p. at any given time. Owing to the fact that where a large number of customers are being supplied with power, it is certain that they will not all require at the same time the maximum power which their motors can develop, it should be possible from such a plant to supply motors aggregating not less than 20,000 h. p.

And now, would it pay? In the above estimates nothing has been said about dividends, but any private corporation that would undertake to install such a plant would probably expect

not less than 10 per cent. upon their investment; 10 per cent. of $3,000,000 is $300,000, and adding this to the annual charges against the plant as calculated, and adding also $100,-000 for general expenses, we have a total of $1,000,000 per annum. Dividing this by 20,000 h. p.—the aggregate power of the motors which it is estimated could be safely supplied–we have $50 per horse-power per year as the price at which the central station company could contract to sell a horse power for one year. This figure is, I believe, very considerably under the cost of the average horse-power year in Pittsburg, if we exclude from consideration the very large plants, say those exceeding 2,000 horse-power. The actual cost of the power to the users, however, would be increased by a fair annual charge against their investment in transformers and motors. This investment would vary between wide limits, depending upon the amount of power required.

The following table shows approximately what this investment will be, the costs given covering transformers and Tesla polyphase motors:

Output of Motor.	Total Cost.	Cost per H. P.
1 h. p.	$150.	$150.
5 h. p.	320.	64.
10 h. p.	520.	52.
20 h. p.	850.	42.50.
40 h. p.	1,400.	35.
50 h. p.	1,650.	33.
100 h. p.	3,000.	30.
200 h. p.	5,000.	25.

The power should be sold by meter. Within the present year an improved type of alternating current meter, the invention of Mr. O. B. Shallenberger, of Rochester, Pa., has been added to the list of electrical devices which make possible such a project as that which I have attempted to outline, and the meter will prove a most effective assistant in extending the sphere of central station supply and securing to careful users the best economy.

The motors themselves will require no attendance which need be taken into account. It is particularly true of alternating current motors that they "run themselves." In shops where they are used the nearest workman closes a switch at seven o'clock in the morning, opens it at twelve, closes it again at 12.45 and opens it when working hours are over. During all this time the motor draws from the circuits only that amount of energy which is required to do its work, and whatever the variations in the load may be they cannot occur more suddenly than the current will change to meet the requirements of the new load. The meter will record each horse-power upon dials similar to those used in gas and water meters.

Each man will pay for the power he uses and no more. The central station company will naturally establish a sliding scale of rates; in other words will discount bills by a percentage increasing somewhat in proportion to the size of the bill. The use of meters will very possibly make it practicable to connect to the circuits motors aggregating considerably more than twenty thousand horse-power, but how much more only experience can determine.

DISCUSSION.

The President. Gentlemen, you have heard a very interesting paper, and your applause indicates that you appreciate it. The subject is now before you for discussion.

Mr. Geo. S. Davison. There is one very important argument in favor of the plan of locating the generating plant close to the city and therefore near the points of distribution. Fortunately Mr. Stillwell's calculations show this to be the more economical plan. I say fortunately for the reason that there is no point of location for the generating plant, within ten miles of Pittsburg, where such a plant could secure coal direct from the mine, and at the same time have a sufficient supply of that most needful agent, water. Such a large plant as this must be located along one of our large rivers, as all the

smaller streams run dry in the summer months. Speaking of water reminds me that I did not notice that Mr. Stillwell added anything to the cost and operation of his plant for procuring and pumping water for his boilers. I would assume that the better plan would be to pay for the transporting of the coal to a convenient point for getting water, and that point can be as close to the point of distributing the power as desirable.

The President. Mr. Schluederberg, can you tell us anything about the fuel question in this problem ?

Mr. G. W. Schluederberg. As far as the fuel is concerned, I think it can be gotten for considerably less than stated. The gentleman was, of course, on the safe side. I think that at the present time, coal well adapted for the purpose could be obtained in the city for about one-half the price given. I quite agree with Mr. Davison that while coal might be bought a little cheaper ten or fifteen miles outside the city, I do not know of any place within twenty-five miles where there would be water enough for the purpose. I know that at present there is not enough water in the country to run the machinery at the mines that are producing coal.

A Member. Do I understand that a condensing engine could be run with an internal economy of 97 per cent.,—that is run a dynamo with only a loss of 3 per cent.?

Mr. L. B. Stillwell. No, I did not say that ; I made no assumption as to the efficiency of the engine. I simply took what Dr. Emery says in regard to the engine, and put a little margin around it. I assumed *20,000 H. P. delivered to the generators.*

A Member. Not indicated horse-power ?

Mr. Stillwell. No ; mechanical horse-power delivered at the shaft.

I would like to suggest that if a paper like this is to have any value, or lead to any new information, some members of the Society ought to give us figures from their experience as to the actual cost of power in Pittsburg, in plants of various

sizes. I have no doubt that many of the gentlemen here have some facts on this subject which would be pertinent, and which would enable us to form a more accurate judgment as to whether this scheme is feasible or not.

Mr. W. A. Bole. I understood Mr. Stillwell to say that he had left out of his calculations the efficiency of the original engine, and that 65 per cent. represented the efficiency of the plant. If this item is taken into account, and the friction of the original engine is assumed to be about 10 per cent., which is probably right, it will make the efficiency of the total outfit about 58 per cent. instead of 65 per cent. In other words, for every 58 horse-power delivered to the user, 100 horse-power would have to be generated up in the country. As Mr. Stillwell has concluded that it would pay to bring his plant closer to the city, haul his coal a little further, and carry his current a shorter distance, I think it is fair to presume that bringing it still closer, or into the mill, would be still better. Coal can be transported from the mine to the mill, a distance of from fifteen to twenty miles, for probably ten or fifteen dollars a barge load, and what that would figure out in horse-power units would be so small that one would have to have a sharp pencil to note it down. If the units that Mr. Stillwell has suggested, 25,000 horse-power each, were utilized in the mill, I see no reason why we could not get a horse-power about as economically in the mill as in that original station in the country. Therefore, from the standpoint of dollars and cents, I do not see much likelihood of that scheme paying. It would be a nice thing to do away with the smoke and dirt, but people that had to install mills would have to spend almost as much money, I take it, for motors and electric apparatus as they now do for engines and boilers. In regard to the wages of employes, the employers would probably have to pay almost as much for the taking care of the motors, transformers and other electric appliances as they would for firing coal under boilers and operating steam engines. I think Mr. Stillwell says that the total cost of the electric ap-

paratus for a plant of about 100 horse-power would be about \$25 or \$30 per horse-power. With steam plants, if a man is economical, he can put in certain types of engine and boiler to cover the whole thing with that amount of money, or nearly so. So that I think there are a good many difficulties about this scheme from a money-making standpoint. The Niagara Falls Company seem to be unable to induce anybody at Buffalo, as near as I can determine from reading the newspapers, to put in their power there. Buying the electric power at Niagara Falls, I think the lowest price is \$45 or \$50 per horse-power. They cannot afford to sell it for less than that, and get anything for their power at Niagara Falls. The manufacturers at Buffalo cannot see much advantage in it. I do not see why the same conditions should not prevail at Pittsburg. Mr. Still-well's paper should be studied more at leisure ; many things in it cannot be digested at first sight.

Mr. Stillwell. Mr. President ;—Mr Bole's remarks furnish considerable food for thought. I am sorry that I have not been able to have the paper printed and handed to the members of the Society, because the calculations cannot well be followed from the reading. I think, in reading hastily, I must have failed to make myself clear in several points to which Mr. Bole has referred. I did not investigate the efficiency of the engine for the reason that my paper does not require it. I simply take two plants and compare them ; in each of them I assume that I have 20,000 horse-power delivered to the shafts of the generators. I do not care what the indicated horse-power of the engines may be. That is another question, and is covered by Dr. Emery's figuring. He has calculated all that, and he finds a lump figure, \$355,000 per annum, required to operate a plant capable of delivering at the generator shafts 20,000 horse-power, under certain conditions of load line, which he assumed, and which I stated. I do not think that because the comparison of the two plans for this large central station scheme, one of which supplies its power at a distance, and the

other local, has led us to the conclusion that it is better to move the central station near to the work, it can be used logically as a basis for the inference which Mr. Bole draws, namely, that it would be better to move the coal to the plants and put it under the boilers. I do not see the relation of the facts I stated to the conclusion which he draws. As to the attendance at the motors, I want to make an emphatic statement. The attendance required for motors is not nearly so much as required for steam plants. As a matter of fact, at our shops, those of the Westinghouse Company, the attendance is confined to simply an inspection about twice in twenty-four hours by one inspector, attending to 60 motors, with no one watching them. I never saw an engine that would do that for a very long period. Where I say "efficiency" I am speaking of my part of it. In speaking of efficiency I am talking about the electric plant, and I am dividing the output by the input, and not caring whether the engines have an internal economy of 95 per cent. or 75 per cent. Mr. Bole is considerably in error in regard to the Niagara Falls Power Co., when he says that they seem to be unable to furnish Buffalo with power at less than $50 per horse-power. I understand why he is in error; he went to the newspapers. The fact is that the Niagara Falls Power Co. has made a proposition to the city of Buffalo to furnish 10,000 horse-power, delivered in the city, at rates varying with the amount called for, and the highest price they have asked in any proposition I have seen is under $25. As a matter of fact, they have closed some contracts under $20 for power at the Falls.

I should like to get some information as to the cost of steam power in Pittsburg.

Mr. W. E. Koch. Mr. Bole stirred me up by his paper and I worked pretty hard to determine the cost of annual horse-power, and came to the conclusion that, taking 1,000 horse-power plants, running at 100 pounds pressure, and using what I call a fair average working load, the cost was $40.20 per annual horse-power. But if you take one or two boilers, and

run the pressure up to 150, 180, or 200 pounds, as some are doing now, the cost will go down tremendously. It makes an enormous difference whether you are running your boilers at 100 pounds or at 120 pounds, and at 150 pounds pressure the cost per horse-power comes somewhere near $30. I think with a good plant, with everything in good order, and with coal at about one dollar and a quarter per ton,—we have here the finest coal in the world ; our coal averages only 5 per cent. ash ; there is nothing better than that for fuel,—and using it properly, running one or two boilers, and at 150 pounds steam pressure, the cost can be brought down very much. I am very much obliged to these electric people. If they will only tell us at what price they will be willing to supply power, they will stir us up so that we can get down to that price ourselves. They are doing us a very great service. There comes up another question, namely, whether we will not be doing things cheaper and better, and get rid of the smoke, by gasifying our coal. The pipes are already laid in the city, and we must be pretty poor scientific men and chemists if we cannot make a supply of gas from our coal: It may not be as good as natural gas, but it should be something that will take its place. We have got gas down to 48 per cent. nitrogen ; if we get it down 20 per cent. more we will have just as good gas, and piped as easily, as natural gas. I am looking forward to that to help us, and then we can use gas engines as our friends in France do. They use large gas-engines, gasifying the coal and using the gas. That seems to be an immense advance in the right direction.

MR. STILLWELL. I would like to ask the gentleman what kind of a load line at $30 a horse-power and what kind of service?

MR. KOCH. 10-hour service.

MR. E. SWENSSON. Is that horse-power delivered at the engine or at the machines?

MR. KOCH. Delivered at the engines.

MR. SWENSSON. Then it will be about $60 a horse-power before using, or at the machines?

Mr. Bole. I wish to qualify my criticisms as follows: For the time being, I imagined I was Mr. Carnegie; that I had a mill, and wanted to use 2,500 horse-power. Under those conditions, I could not see any inducement to sell the engines and boilers, and buy the motors and put in the plant. The matter takes a very different aspect if applied to smaller plants. I think it has been stated here before, and I believe it to be true, that it is not the smoke that the Homestead Mills or Edgar Thomson Steel Works produce that makes Pittsburg unpleasant, but it is the smoke that comes from the little dry-goods store plants, such as are located along Fifth Avenue and Smithfield Street. The nuisance is largely due to the small plants that are in the location to do the greatest amount of mischief. Those small plants, of course, cannot be made to develope a horse-power for nearly so low a figure as a large mill can, and the man that is running a dry-goods store, and wants ten or fifteen horse-power to run his elevators, and similiar service, can afford to consider the purchase of this power. He might do well to buy his power, and the company might do well to sell it to him.

Mr. Harry J. Lewis. There is another phase of this question brought out by what Mr. Bole has said. The people who would use this power would probably be those who would use it in small sub-divisions; that is, people who would want nearer from 25 to 100 horse-power than those who would want 2,500, and they are also the most persistent smokers. There is another feature in this subject: In our office and business buildings, they want not only power but heat, and I would like to ask Mr. Stillwell what the possible efficiency of the electric radiator is, and whether he could supply the double requirement of a modern building, which would seem to be the first market for his power delivered in the city.

Mr. Stillwell. In regard to heating, I do not think there is any probability that electricity will be used for heating purposes except in what might be called fancy cases

where people want something extremely convenient, extremely compact, and very readily handled. The general reason for the inability to use electricity for heating purposes is, of course, understood. We compete there with coal at its best, and if all the chemists were to go to work to produce a form of stored energy, they could not store it in a better form than coal. But when we come to burn that coal, we throw away nine-tenths of it before we can get the mechanical power, and we have to get the mechanical power before we get the electricity. The efficiency of the electric radiator is 100 per cent. But we start with too heavy a handicap.

Mr. Bole touched upon one point, or at least he suggested to me one point which probably he did not have in mind himself. When he first spoke he had in mind Carnegie's mills using 2,500 horse-power, and drew some inferences about bringing the coal nearer to the boilers. They are using at least three thousand horse-power of electric motors in that mill, which brings up the point that electricity possesses a great advantage in the distribution of power; for your 2,500 horse-power on the shaft is not 2,500 horse-power at the point where you want to use it.

I think there must be something in this scheme of using electricity. I inquired in the city as to the rates paid for motors, and I find that some people using ten horse-power pay $100 a year a horse-power. Either the steam plants must be very expensive, or the motors must require attendance, or something else must explain that fact. I think, judging from some experience I had around Buffalo recently, that the users of steam engines all over this country are somewhat at a loss to find out what their power costs them. The reason is obvious; the steam plant is generally a side interest with them. When they are running a mill or something of that kind, they have not the time to look after the exact cost of this or that item. In a central station plant we get away from that. When you concentrate on the plant the attention of your best

engineers and skilled firemen, you can prevent all this boiler leakage, and all this stupidity on the part of firemen, which Mr. Daniel Ashworth told the Society about. You can get the best results in such a plant. In Buffalo, the papers had a great deal to say about what power ought to cost and ought not to cost. The Niagara Falls Company employed a steam engineer to go to Buffalo and call on these newspapers, and suggest to them that, with their permission, the Niagara Falls Power Company would like to pay the expense of a test to determine what the power in their printing offices was costing them. In one case, the owner of a paper that had been particularly vociferous in favor of a limit of $15, admitted, after he went over the figures, that he was paying $140 per annum per horse-power. Even the city water works run above $60 per horse-power per annum, this figure being based on their mean power, not their maximum. One source of difficulty and error is that the users of steam power usually divide their expenses, omitting some items which should be included, by the maximum power of their boilers. One of these Buffalo newspaper men, after one of these tests, went to a well-posted gentleman in Buffalo, and asked what was the matter. The gentleman said, "There are two reasons why your calculations are wrong: your dividend is too small, and your divisor is too large." That is the trouble with the steam-power men. I should like to draw out some more facts, and get the actual cost of steam power.

Mr. G. E. Flanagan. There is one thing that strikes me in favor of Mr. Stillwell's proposition. The great difficulty with the people that own stores and office buildings in the city, which have been termed the small smokers, is to find a place to put their plant. It is not only the cost of the plant itself and the running of it, but the location of it in their buildings. It is usually located in the cellar, in an out-of-the-way corner, and in a place which does not admit of extension or development in case it is found insufficient for the purpose required, and it usually has to remain insufficient. Two or three stories

may be added to a building, but there is no more room in the cellar to increase the power plant. I would like to ask Mr. Stillwell a question in regard to his remark that the electric motor takes only the power which it gives up again. Does that apply to a motor running under its full load? Does it also apply to a large motor wired and installed for doing heavy work, and running under a small percentage of its maximum load?

Mr. Stillwell. I did not mean to say that the motors draw only power exactly equal to that given up. Of course, there is a loss in the motors. The power is closely proportionate to that which they give up. A motor which will work under a full load at 90 per cent. efficiency, will work under a half load (even an ordinary motor) at 86 or 87 per cent. As motors are now generally designed, they aim to give, and succeed in giving their best efficiency not at a full load, but at about three-quarters load, in order to meet the conditions of actual service. I had hoped to have some lantern slides here to show that. I wanted to show the efficiency curve of a motor ; it is a remarkably straight line between the limits of 40 per cent. and 120 per cent. load.

Mr. Swensson. Mr. Stillwell says that the steam users do not know what the steam costs them. That is very likely literally true. I think, however, you can count on from $30 to $40 per horse-power per annum. There is also something else they do not know ; that is, what does electricity cost? However, it is not always a question of economy whether steam or electricity is used. Mr. Stillwell mentioned that electricity was used at Homestead, but it is probably not used on account of economy so much as on account of speed and convenience, which is a very important point. When you want to increase the output of a plant, it does not always matter about the first cost of the means employed, if in the end only economy is the result.

If the use of electricity will greaty increase the speed of

operation and consequently the output of a given plant, it may be and probably is, economy, even if the electrical machinery and the power of operating it should be more expensive than steam. On investigation, I think that in many instances it will be found that this is the real reason for using electricity.

Mr. Stillwell. That is a good point I had not thought of. I would like to ask the gentleman who last spoke to define a little more closely what he means by power costing between $30 and $40.

Mr. Swensson. 10-hour service and at the engine.

Mr. Stillwell. What is the size of the engine?

Mr. Swensson. Say about 100 horse-power, carrying about 90 pounds of steam.

Mr. Stillwell. Do you include in that estimate the capital charges, as well as attendance, coal, oil, etc?

Mr. Swensson. Everything that is connected with producing the steam and running the engine, but not the distribution.

Mr. Stillwell. In the 100 horse-power engine, that figure would be based, I presume, upon the maximum output. You estimate that plant would cost you about $3000 per annum to operate?

Mr. Swensson. Yes, sir.

Mr. Stillwell. If you take these figures I gave, viz.: 20,000 horse-power produced for sale, and divide the 20,000 into the estimated cost of operating, say $900,000, you will have $45 for your flat rate. If you sell by meter you will take full advantage of the fact that one man has his switches off when another man has his on.

Mr. Swensson. Then I would like to ask Mr. Stillwell where the power of the steam engine and central station motor goes when the electric power is not used.

Mr. Stillwell. I think that is covered by the assumption which Dr. Emery made in regard to the load line. He assumed that the full 20,000 horse-power will be delivered

for 10 hours a day, that 12,000 horse-power will be delivered for another 10 hours, and 5,000 horse-power will be delivered for 4 hours a day, stopping the engines from time to time as the load decreases, and starting them up as the load increases. Dr. Emery's calculations included, as I read them, an allowance for the banking of fires, and the loss due to radiation, when the load is varying in that way.

Mr. Swensson. It seems to me it would be hard to do that when the power is so far away from the central station. How will they know in time to shut down? Conditions are just the same as with the steam engine, it is not loaded full all the time, and consequently the steam is not used to same advantage all the time. When the motors are not being used, the men at the central station could not be aware of it in time to regulate the power closely, not even as closely as at a local steam engine and consequently the cost per horse-power in both cases would be affected in the same proportion from this cause, and your figuring that my steam engine would cost $60 per horse-power on account of not utilizing more than 50 horse-powers on an average out of the 100, would apply equally well to your central electric station, if not more so, and your horse-power would cost $90.

Mr. Stillwell. The annual charges are $900,000; divide by the maximum, 20,000 horse-power, and you will have $45 for your flat rate, which is the one I would use in comparing with the ordinary method of estimating the cost of steam power; but talking of mean values, you want to divide 900,000 by the mean load, which is 12,760 horse-power under Dr. Emery's assumptions, and it gives you about $75 per horse-power.

Mr. Swensson. In the first case, the cost of a steam engine horse-power would be $30, because that is based on the yearly average cost of operating the 100 horse-power engine.

Mr. Stillwell. You are not making allowance for this one fact, viz.: that with the central station, delivering

at any given time, 12,000 horse-power, or 14,000 horse-power, we can contract for the sale, 20,000 or possibly 25,000 horse-power.

The President. I would like to ask Mr. Stillwell as to the degree of reliability of the meter he speaks of. How closely does its indications measure the actual power developed or used?

Mr. Stillwell. The meter used with motors would measure the energy to the motor. The rate would have to be fixed so as to be equitable, and cover the constant loss in the motor. The losses in the motor are not very far from constant. As to the accuracy of the meter, I think it would be fair to say that the error would not exceed 3 per cent. They are guaranteed to be accurate within about 1 per cent., but in service they do not maintain that. They are exceedingly delicate instruments of measurement. It is a peculiar thing about electricity that although we cannot see it, we can measure it more accurately than almost anything else we deal with.

Mr. Bole. Mr. Stillwell asks for contributions of data, which is certainly in order, and I would like to contribute one item which may be of use to him to show the difficulty of selling high-priced power in Pittsburg. The Westinghouse Machine Co. have two boilers of very good efficiency. The total horse-power is probably about 550. 550 horse-power is a fair statement of our average evaporation, allowing 30 pounds of water to a horse-power. We use Pittsburg coal (slack) which costs us, exclusive of the cost of cartage, about 70 cents a ton. It costs us $275 a month, or half a dollar a horse-power a month to evaporate 30 pounds of water into steam; that would mean $6 a year for single-turn duty; and if engines as economical as Dr. Emery's would be used, which would only require about 14 pounds of water a horse-power instead of 30. Then in Pittsburg where coal is cheap, an annual horse-power could be produced, double turn, for about $6 a year for the fuel only.

MR. KOCH. I would like to ask Mr. Stillwell what steam pressure he has used in his calculations?

MR. STILLWELL. I should have to refer to Dr. Emery's paper in order to answer that question. He took a high pressure, 140 or 150 pounds, and calculated everything from what he considers the best steam practice. I have seen a few figures of foreign engines which were a little better than his, but not materially.

It was moved and seconded that the discussion of this paper be continued at the next meeting. Carried.

COST OF POWER IN A LARGE STORE BUILDING IN PITTSBURG.

CONTRIBUTED BY MR. PHILIP PRICE BARTON.

In this case, which in many respects is perhaps a typical one, the power is used for driving a thirty light arc dynamo and a 6 K. W. incandescent dynamo to which are connected thirty 9.6 ampere arc lamps and ninety 16 C. P. incandescent lamps. It is developed by means of a 66in. × 16 ft. 100 H. P. horizontal tubular boiler supplying steam to a 9in. × 12in. 50 H. P. Ball engine, to which the dynamos are belted direct. Exhaust steam is used to heat the building from October 1st to April 1st. When driving 90 incandescent lamps and 30 arcs the engine with free exhaust indicates 46 H. P. A reasonable allowance for engine friction suggests about 40 brake H. P. for the above load, of which 30 H. P. may be assumed to be required by the arcs and 10 H. P. for the incandescent lights.

The plant runs six days each week, starting at 8 A. M. and stopping at 11 P. M. every day but Saturday, when it stops at 10 P. M. This is practically 15 hour service. The running schedule is as follows:

90 incandescent lights run daily from 8 A. M. till 6 P. M. and on Saturdays until 10 P. M.

10 H. P. × 10 hrs. × 5 da. plus 10 H. P. × 14 hrs. × 1 da. = 640 H. P. hours per week.

22 arcs run daily from 8 A. M. till 6 P. M. and on Saturdays till 10 P. M. 22 H. P. ×10 hrs. ×5 da. plus 22 H. P. ×14 hrs. ×1 da. = 1408 H. P. hours per week.

8 arcs run daily from dusk till 11 P. M. excepting Saturdays, when they stop at 10 P. M. Average time of starting 6 P. M.

8 H. P+5 hrs. ×5 da. plus 8 H. P. ×4 hrs. ×1 da. = 232 H. P. hours per week.

Total H. P. hours per week, 2280.

Total hours run per week, 89.

Average load at engine shaft, 25.6 H. P.

The present cost of the above engine and boiler installed may be estimated at $2,000.

Run of mine coal at 4½ cents per bushel is used for fuel, and costs from April 1st to October 1st $50 per month, or $300.

From October 1st to April 1st the expense for fuel averages $70 per month, or $420 for the six winter months. During these winter months the 8 arcs which start at dusk may be assumed to average two hours longer in daily service than they do in the summer months. The remainder of the power load is uniform throughout the year and the increased fuel consumption in the winter months is due to the back pressure load on the engine caused by the heating system, and to about 96 H. P. hours per week, due to the increased time of service of 8 arc lamps. This winter *power* load is nearly 5 per cent. greater than the summer load and we therefore add 5 per cent. to the cost of fuel for the summer months and thus obtain $315 for the fuel expense of the power load for the six winter months, or $615 for the year.

The maintenance and operating expenses are then as follows:

Interest on investment at 6 per cent. .	$ 120 00
Depreciation and repairs at 6 per cent.	120 00
Labor : Engineer and assistant	1,950 00
Oil	75 00
Waste	8 00

Hauling Ashes....................	40 00
Water. Estimated from data furnished by city officials..................	150 00
Fuel..............................	615 00
Rent of space occupied by engine and boiler...........................	150 00
Insurance and taxes. Estimated.....	60 00
Total........................	$3,288 00

This is the annual cost of 25.6 average H. P. at the engine shaft. The cost per annual horse-power for fifteen hour service is therefore in this case $128.44.

Adjourned.

DANIEL CARHART,
Secretary.

MEETING OF THE CHEMICAL SECTION.

ALLEGHENY, PA., Dec. 20, 1895.

The regular meeting of the Chemical Section was held in the lecture room of the Carnegie Library building on the above date.

The meeting was called to order at 8:10 P. M. by chairman J. M. Camp; eleven members and two visitors being present.

The minutes of the last meeting were read and approved. The following nominating committee was appointed by the chairman on Nov. 25, 1895: Prof. F. C. Phillips, Mr. W. H. Coster and Mr. W. E. Garrigues. They were not ready for final report at this meeting.

Moved and seconded that ballot for officers for the ensuing year be sent out with notice for next meeting. Carried.

The committee on Chemical Literature called attention to the following article:

"The Experimental Water Filter Tank at Pittsburg, Pa.," in the Engineering News, Vol. 34, No. 24, page 390.

A paper entitled, "Laboratory Notes on Analytical Methods," by W. E. Garrigues and Gustave Mueller, was then read by Mr. Garrigues.

The paper was discussed by the chairman, the authors, Prof. F. C. Phillips, Messrs. A. G. McKenna, H. S. Menough and A. D. Wilkins.

Prof. F. C. Phillips reported that two of the members of the committee to the Water Commission had resigned. The chairman announced that he would appoint two members to fill the vacancies later.

Moved and seconded that Messrs. Garrigues and Mueller be tendered a vote of thanks for their paper. Carried.

LABORATORY NOTES ON ANALYTICAL METHODS.

BY W. E. GARRIGUES AND GUSTAVE MUELLER.

Under this title we have brought together a variety of matter, being chiefly modifications of old processes, none of which seemed of sufficient importance to singly form the subject of a paper. These do not represent experiments undertaken for the purpose of gaining knowledge in a general sense, but rather such as were forced upon us from time to time, through a recognized lack of efficiency or speed in the original methods, and the changes we advocate have since become our daily usage.

We believe it to be for the best interests of our profession that chemists everywhere make it a practice to place on record the many little details in analysis—either from a critical or reformatory point of view—which are of necessity discovered in every laboratory. The art of chemical analysis is to-day of such immense scope that only special study, induced by daily requirement of knowledge in one, or at most a few branches of industry, can make any one man familiar with the all important details in manipulation that are the chief essentials to accuracy.

We say 'chief' because the general outlines of any method with which one is not conversant, may usually be obtained in scores of text-books, but this is true of the details only in rare instances. Let every chemist note the little changes in his daily practice, which experience tells him are for the better, have them put on record in the columns of a technical journal where others who feel so disposed may profit by them, and the labors of all will be lightened.

This paper will include: 1, The determination of chlorine in chlorides; 2, available chlorine in bleaching powder; 3, temporary and permanent hardness of water; 4, free carbonic acid in solution; 5, preparation of a standard caustic alkali solution free from carbonates; 6, solution of a substance

rich in organic matter for the determination of phosphoric acid: 7, determination of fixed alkalis; 8, copper in ores and alloys; 9, the use of the Gooch filter-crucible.

1. THE DETERMINATION OF CHLORINE IN CHLORIDES.

It is frequently desired to find the quantity of this element in a solution which is not neutral; in that case, Mohr's method cannot be directly applied.

The acid liquid is made alkaline with sodium carbonate in excess and filtered. (If phosphoric acid is present, ferric nitrate is first added to remove it as ferric phosphate). The filtrate is faintly tinted with methyl orange and slightly acidified with dilute nitric acid, bringing it just back to the yellow color with sodium carbonate. The titration with silver nitrate and potassium chromate is then proceeded with as usual, the color of methyl orange not in the least interferring.

Should the quantity of chlorine be very small, i. e., sufficient to produce with silver only a faint opalescense, the end reaction is always quite indefinite; the change from yellow to red being much less marked than that from white to red. To overcome this, 5 c. c. of saturated barium nitrate solution are added to the neutralized liquid, followed by 5 c. c. 10 per cent. potassium chromate solution. It is then titrated with silver nitrate. The silver chromate appears very sharply against the dense precipitate of barium chromate, (or sulphate, if that acid be present in excess of the barium added).

This mode of procedure is especially serviceable where small quantities of both sulphuric acid and chlorine are to be determined. The bases (and phosphates) are then precipitated as before, the liquid made just acid to methyl orange and sulphuric acid precipitated with 5 c. c. barium nitrate. The filtrate is then neutralized, 5 c. c. of chromate added and titrated for chlorine. Heating the solution for precipitating barium sulphate sometimes destroys the color of the methyl orange, when of course more must be added.

The statement of several writers that the slightest excess of sodium carbonate vitiates the result of the titration with silver and chromate indicator, we find to be entirely erroneous. Sodium hydrate has much more marked tendency in this direction. Thus: In the presence of 0.5 c.c. normal sodium hydrate, no end reaction could be distinguished, the solution acquiring a dirty brown color, while 1 c. c. normal sodium carbonate had no deleterious effect whatever. Any considerable quantity however decidedly did have, and instructions to titrate the water solution of a carbonate and nitrate fusion directly, are altogether impracticable.

Under any circumstances the presence of considerable quantities of sodium nitrate prevents the determination of chlorine in this way, the silver chromate being then appreciably soluble. The liquid is best acidified with nitric acid and the chlorine precipitated with silver nitrate, filtered through a Gooch crucible, the water washings displaced with alcohol, dried at 120 and weighed. The results are extremely accurate.

AVAILABLE CHLORINE IN BLEACHING POWDER.

Bunsen's method of titrating the iodine liberated in hydrochloric solution from potassium iodide, by hypochlorous acid, is criticised on the ground that it returns likewise the chloric acid present.

Whether or not the criticism is a just one we can not judge, as we lack the original details of the process. At any rate, however, it can at best be true only in part.

When concentrated hydrochloric acid is added to the mixed solution of bleaching powder and potassium iodide, if it contain also—as it frequently does—a small amount of calcium chlorate, the latter will liberate iodine in proportion to the volume of acid added. The reaction is, however, never even nearly complete.

Still the apparently small error becomes greatly magnified through the fact of calcium chlorate liberating six equivalents

of iodine against one of chlorine present while the hypocholrite liberates but one.

When hydrochloric acid diluted with three volumes of water and cooled, is used for the decomposition, thereby avoiding local heating of the solution to which it is added, no iodine is liberated by the chlorate—at least unless an unwarranted excess be employed ; and even then only traces.

The whole process then is: To the solution of the bleaching powder in a flask, add potassium iodide solution, then 1:3 hydrochloric acid and titrate the liberated iodine with sodium thiosulphate and starch. Calculate to equivalent of chlorine.

This is so delightfully simple that we want to raise our voices in protest against substituting any of the more complicated methods.

TEMPORARY AND PERMANENT HARDNESS OF WATER.

This determination, we note with pleasure, is gradually being dropped from the list formerly constituting a sanitary analysis, but in the case of water intended for many industrial purposes—notably boiling soap and raising steam—we view it as of pre-eminent importance. Clark's soap method is certainly a crude affair, and as it lacks the redeeming feature of great convenience, we much prefer an alkalimetric one.

A portion, not exceeding 100 c. c., is tinted with methyl orange and titratèd cold with deci normal acid ; this is a measure of the temporary hardness. A second portion, of any quantity, owing to the nature of the water under examination (300 c. c. if unknown) is evaporated to dryness in platinum, with excess of deci normal sodium carbonate; residue taken up with boiled water and filtered through small paper. The filtrate is then tinted with methyl orange and titrated with deci normal acid.

The difference between this and the volume of alkali previously added, is a measure of the permanent hardness. In case a negative result be obtained here, i. e., should the acid re-

quired exceed the alkali used, the difference is a measure of sodium carbonate present in the water and this must be deducted from the temporary hardness found.

In titrating with the deci normal solutions and methyl orange, very little of the indicator must be used, as otherwise the end point becomes obscure. One drop of a solution of 1 grain in a litre of water is ample for each 50 c. c. of the liquid to be titrated.

Sutton in his Volumetric Analysis, notes the claim of some writers that frequently samples of methyl orange are met with which are unreliable as indicators, but he deprecates their opinion. In this connection, we wish to say that out of four bottles obtained in this city during the past year, three were found altogether useless. These had in each case an orange yellow color, while the one good sample was decidedly orange red. Whether or not this distinction holds good throughout we cannot say.

FREE CARBONIC ACID IN SOLUTION.

Aside from the analysis of mineral water this determination is at times useful in ascertaining means of softening hard water to be used for raising steam.

Our method is a modification of Pettenkofer's and has the advantage of doing away with the use of barium hydrate solution, which is much more difficult to prepare and to handle without access of carbonic acid than sodium hydrate.

With ordinary water a measure of the sample is poured into a graduated flask containing barium chloride solution, followed by deci normal sodium hydrate, free from carbonate. The liquid is then diluted to the mark, passed rapidly through a larger plaited filter and an aliquot withdrawn for titration with deci normal acid, using preferably phenolphthalein as indicator. The alkali added, less the acid required to establish neutrality, is a measure of free carbonic acid : free being taken to mean all except that combined as normal carbonate. Each c. c. of deci normal is equivalent to 0.0022 grams CO_2.

In the event of much magnesia being present it might be necessary to add ammonium chloride along with the barium chloride, in which case phenolphthlein must be replaced by any one of the other indicators.

When a carbonated mineral water is to be dealt with, the cork of the bottle containing the sample is pierced with a stop cock arrangement, and the escaping gas bubbled through the mixed solution of barium chloride and sodium hydrate (in this case normal) until no more is evolved on shaking the bottle. The latter is then disconnected and its contents poured into the absorbing flask, after which the procedure is the same as for ordinary water.

The carbonic acid free caustic solution is very easily prepared in the following manner: pour into a bottle of good stick caustic, water in quantity insufficient to dissolve all the alkali and let stand until settled clear. Draw out with a pipette and dilute as required.

When the solid caustic dissolves, the solution heats immediately, and as the solubility increases greatly with the temperature, we get a super-saturated solution. On cooling, this again deposits alkali and the carbonate being much less soluble than the hydrate, is all eliminated. Not the least trace of it can be found in the clear liquor.

THE DETERMINATION OF FIXED ALKALIS.

In the usual course of analysis, after precipitating sulphuric acid with barium chloride and the other bases and phosphoric acid with barium hydrate, instead of removing the excess of barium with ammonium carbonate and subsequently obtaining the alkalis as chlorides, we remove the barium with sulphuric acid, evaporate, ignite and weigh the sulphates. We thus avoid the always delicate task of volotilizing ammonium chloride from the residue without any loss of soda or potash, as the alkali sulphates will safely stand the full heat of a Bunsen burner.

If it is only desired to know the combined alkalis, sulphuric

acid is determined in the residue, calculated to SO_4 or SO_3 as the case may be, and this weight deducted from that of the combined sulphates. The remainder is K+Na or K_2O+Na_2O respectively.

For separating the potash, the Lindo-Gladding method is employed, the details of which for the sake of completeness we copy from Bull. 38 U. S. Dept. Agr. Division of Chemistry.

"This residue is dissolved in hot water, plus a few drops of hydro chloric acid, and a slight excess of platinum solution is now added. This solution is then evaporated to a thick paste in a small dish, and 80 per cent. alcohol added. In evaporating, special precaution should be taken to prevent absorption of ammonia. The precipitate is washed thoroughly with alcohol by decantation and on the filter, as usual. The washing should be continued even after the filtrate is colorless. Ten c.c. of the ammonium chloride solution, prepared as hereafter directed, are now run through the filter, or the washing may be performed in the dish. The 10 c. c. will contain the bulk of impurities, and are thrown away. Fresh portions of 10 c. c. of the ammonium chloride are now run through the filter several times (5 or 6). The filter is then washed thoroughly with pure alcohol, dried, and weighed as usual. Care should be taken that the precipitate is perfectly soluble in water. The platinum solution used contains 1 dram of metallic platinum in every 10 c. c. To prepare the washing solution of ammonium chloride, place in a bottle of 500 c. c. of water 100 grams of ammonium chloride; shake till dissolved. Now, pulverize 5 or 10 grams of potassium platinic chloride, put in the bottle, and shake at intervals for six or eight hours; let settle over night, then filter off the liquid into a second bottle. The first bottle is then ready for preparation of a fresh supply when needed."

The language is not so clear as it might be; the washing 5 or 6 times with ammonium chloride solution, has reference to only one portion of 10 c. c. which is repassed that often. The

alcohol wash must not exceed 80 per cent. by weight (sp. gr. 0.848) otherwise ammonium chloride remains insoluble. A Gooch is the most satisfactory filter to employ.

SOLUTION OF A SUBSTANCE RICH IN ORGANIC MATTER FOR THE DETERMINATION OF PHOSPHORIC ACID.

In case the phosphoric acid be present as mono or dicalcic phosphate, ignition to destroy organic matter is not permissible, owing to the formation of meta and pyro phosphoric acid, which subsequently in part escapes precipitation by molybdate solution. Direct solution in nitric or hydrochloric acid is unsafe as the organic matter dissolved thereby may prevent the precipitation of the phospho-molybdate. Fusion with sodium carbonate and nitrate gives fairly good results but is inconvenient.

Solution in sulphuric acid with the addition of something to aid the oxidation, is free from these objections and at the same time rapid. For this purpose sodium nitrate is best suited, though mercury or potassium sulphate also answer.

1-2 grams of the sample are weighed into a round bottomed flask, of about 250 c. c. capacity, and 15-20 c. c. concentrated sulphuric acid poured on. The flask is heated over a naked flame until the acid fumes, when sodium nitrate in crystals is added until the solution is colorless; the heat being maintained throughout. The time occupied will not exceed five minutes.

DETERMINATION OF COPPER IN ALLOYS AND ORES.

In the absence of appliances for electrolytic deposition, the accurate determination of this metal is in many cases a difficult problem. The well known method of Parkes and Mohr depending upon the decoloration of an ammonical solution of copper by potassium cyanide, is open to the objections of indefinite end reaction and rapid deterioration of the standard cyanide liquor.

Brown's method of titrating the iodine liberated by copper from potassium iodide in sulphuric or nitric acid solution, is free from these objections but is inapplicable in the presence of

iron, lead and arsenic, all of which likewise set free iodine. Brown got rid of these elements by precipitating the copper, lead and arsenic from the iron by sulphuretted hydrogen, dissolving the precipitate after ignition by which arsenic was volatilized, and separating the lead by evaporation to fumes of sulphuric acid. The remaining copper was then titrated as above.

Aside from its tediousness this scheme has several faults. Sulphuretted hydrogen is not a perfect separator of iron and copper, the precitate always containing appreciable quantities of the former metal. Arsenic cannot always be completely volatilized from the mixed precipitate and to counteract the injurious effect of its presence by making the final titration in acetic solution as proposed by Westmorland, is to largely lose the delicate end reaction which is the redeeming feature of the process. It is furthermore practically impossible to ignite copper sulphide without losing more or less of it.

The remedy for these defects is to precipitate the copper from an alkaline solution containing tartaric acid, by means of reducing sugar. Unfortunately, in the case of ores, where much iron is present, the separation is not clean and is best preceded by a sulphuretted hydrogen precipitation. Arsenic and lead, unless present in extraordinarily large proportion, are entirely eliminated in one filtration.

The whole process as applied to alloys is: a quantity equivalent to about 0.2 grams Cu is dissolved in strong nitric acid, diluted to 200 c. c., neutralized with sodium hydrate and just cleared with nitric acid. There are then added 50 c. c. of the alkaline tartrate solution (70 grams sodium hydrate, 200 grams Rochelle salt, to 1 Litre) and the liquid heated to boiling.

A few c. c. of a 5 per cent. solution of commercial glucose are then dropped in, the boiling being meanwhile continued, until the blue color has entirely disappeared and the liquid turns brown from the action of the alkali on the sugar.

After settling 1 hour it is filtered through a double filter,

washed with hot water, dissolved in hot dilute 1-8 nitric acid into a flask, in which it is boiled a few minutes to expel nitrous fumes. The acid liquld is then neutralized with sodium hydrate, just cleared with dilute sulphuric acid and cooled. A few crystals of potassium iodide are next thrown in and the sollution at once titrated with sodium thiosulphate and starch indicator. The thiosulphate is standardized on pure electrolytic copper, dissolving in nitric acid, boiling to expel nitrous, neutralizing, etc.

The thiosulphate can be safely assumed to remain permanent in strength for one month. For the indicator, we strongly recommend the formula called to our attention by Mr. J. M. Camp: 6 grams starch boiled with water 10 minutes and 6 grams zinc chloride dissolved in water added. Dilute to 1 Litre, let stand and decant the clear liquid for use. It keeps indefinitely, and gives a perfect clear blue with iodine.

THE USE OF THE GOOCH-FILTER CRUCIBLE.

Among the most useful pieces of chemical apparatus when one has become familiar with its numerous and varied possibilities, is the combination filter and crucible invented by F. A. Gooch. To designate it an ingenious device is but a poor tribute to its merits.

Under the name of Gooch crucible, it is now familiar to chemists everywhere; all or nearly all, modern text-books on quantitative analysis describe .it in detail, and at least most of the laboratories which have come under our notice possess one or more.

And yet its use is not what might be called common. There are certainly very many analyses in which it could be used to great advantage, both in point of economy of time and accuracy, and to which it is seldom or never applied.

In the ignition of all precipitates where platinum is permissible, and on which the carbon of the filter has either a reducing action or very materially lengthens the time of ignition, the use of the Gooch crucible obviates the whole difficulty.

Take for example a small precipitate of barium sulphate: It has been too often demonstrated to require repetition here, that carbon reduces the sulphate to sulphide. Some chemists have proposed to correct this by subsequent oxidation in various manners. How much simpler it is to employ the Gooch crucible supplied with an asbestos filter bed. In the determination of lead as sulphate, instead of going through all the manipulations to avoid reduction besides using porcelain for the ignition, the precipitate is filtered into a Gooch crucible, the final dilute sulphuric washings displaced by alcohol and the whole dried at 100° C. and weighed. In this case, as in all others, where no ignition is demanded, we substitute for the asbestos fibre, a single disk of filter paper, cut to fit the bottom of the crucible.

In factory routine work, where extreme accuracy is made subservient to speed, a number of these filters may be cut at one time—a five-cent nickel answering admirably for a pattern—and their equal weight assumed. If made with reasonable care they will not differ more than 1 mgm. Our mode of holding the crucible during filtration is to force it partly into the end of a carbon funnel, over the rim of which a piece of wide rubber tubing has been turned.

Every chemist who has often to weigh phosphorus as magnesium pyrophosphate must have found precipitate in which it was all but impossible to burn off the carbon of the filter, furthermore ammonium magnesium phosphate must be washed very many times on an ordinary filter to free it from chlorides, and as is well known, the precipitate is sensibly soluble in the ammonia wash water. All these difficulties are completely overcome by the use of the Gooch crucible, fitted with either asbestos or paper—the quantity of paper is so small that no carbon adheres tenaciously to the precipitate—four washings in the ordinary course of analysis leave the phosphate entirely free from chlorine.

For the determination of phosphorus by either weighing

or titrating the yellow precipitate, the Gooch is admirably adapted. We have found it quite difficult to wash free from acid, especially with large precipitate until we used the Gooch filter. The filtration and washing is performed as rapidly as the liquid can be poured on and the precipitate is then readily washed into a beaker for titration, or may be dried and weighed with considerably more accuracy as well as a saving of time, than if it were on an ordinary filter. In this case the paper disk is preferable to the asbestos. If the titration is to be made with acid and alkali, no small advantage is the absence of so much paper pulp as is of necessity obtained in using a common filter.

Arsenic sulphide, graphite, potassium platinum chloride, and silver chloride are other precipitates for which we have found the Gooch crucible with paper disk a decided improvement. Its use permits of probably the most nearly accurate determination of chlorine possible.

It is unnecessary to enumerate all the possible occasions on which the Gooch might be advantageously employed, therefore we have confined ourselves to our own usage. No doubt many others than those cited will suggest themselves to analysts laboring in different fields.

DISCUSSION.

The Chairman. Gentlemen, there is a wide field for you to plow. I have used a Gooch crucible myself. My principal objection to it is that in using asbestos in the blanket under powerful suction, small particles are pulled through the holes.

Mr. W. E. Garrigues. Some chemists obviate that difficulty by putting glass wool under the asbestos, but in case the crucible is to be ignited, the glass melts, fills up the holes, and runs through.

Prof. F. C. Phillips. By taking fibrous asbestos, flattening it out in a mat and laying another mat across that with fibers at right angles, the finest precipitates can be held

on the filter. You can hold oxalate of lime, freshly precipitated and sulphate of barium. I use a chloride of calcium tube instead of the Gooch crucible.

Mr. Garrigues. Whenever there are no ignitions to be made, I very much prefer a piece of filter paper. The suction keeps it on the bottom, and it is very rarely that anything runs through.

The Chairman. You could use paper with the asbestos.

Mr. Garrigues. Yes, but we generally use the Gooch crucible, with asbestos, for filtering precipitates that would be reduced by the paper during ignition. We use it with paper alone, for filtering the yellow precipitate, and I do not think we ever had a case where the precipitate went through. It holds the precipitate perfectly. I am frank to admit I never could get two weights alike out of a common weighed filter paper. I cannot take a filter paper, prepare it, weigh it and then put it in a funnel and wash with distilled water, put it back, dry and weigh again and get the same weight out of it.

The Chairman. (To Mr. McKenna) you did that, and got good results, did you not?

Mr. A. G. McKenna. I made a number of determinations in that way, getting good results, I think the weights differed about .5 milligram.

Mr. Garrigues. That is pretty good. There is a danger in the first place of carrying some of the filter away, breaking it up and wearing off the edges with the jet of wash water.

Prof. Phillips. In determining copper do you precipitate the copper by grape sugar, in an alkaline fluid and then take the suboxide and redissolve and precipitate with alkali?

Mr. Garrigues. We dissolve the suboxide in nitric acid, then neutralize the excess of acid with alkali, then use the iodide, titrating the liberated iodine.

Mr. H. S. Menough. When you use the filter paper in the bottom of the Gooch crucible, do you find it will hold fine precipitates every time?

Mr. Garrigues. Yes, but some paper is hard to filter through. The best paper I have found for this use is the thinnest I know of ; Munktell's No. 1 F, with a blue stamp on the cover. It is very thin but closely woven. It is the only paper I know of that will separate oil and water clean.

Mr. A. D. Wilkins. Did you ever try precipitating the copper with ammonium or potassium sulpho-cyanide?

Mr. Garrigues. Yes. It is a mean precipitate to hold and is apt to run through. I always use double filter papers, precipitating the copper that way when determining antimony in copper. The precipitate is almost impossible to wash.

Mr. Wilkins. I never had it run through the paper. It comes down granular, filters rapidly and does not run through. I dissolve the alloy in nitric acid, filter off tin and antimony, add sulphuric acid and evaporate to fumes. Dilute and filter of lead, sulphate, neutralize filtrate, add sulphurous acid and a few c. c. of hydrochloric acid, and precipitate copper with either of the above cyanides. Collect on counterpoised filters or single weighed filter and weigh as copper sulphocyanide. ($\times .523 = Cu.$)

Mr. Garrigues. As far as I know, it is a perfect separation of copper from anything else that is ordinarily found with it, except lead. I have thought of applying it to this iodine method, but the precipitate would have to be ignited, and I have had very poor success in igniting copper precipitates ; you are very apt to lose some of the copper.

Mr. Wilkins. The principal objection to the method is that when you add nitric acid to the filtrate from the copper precipitate it gives off prussic acid. The iron, aluminum or zinc have to be determined from a fresh sample.

Mr. Garrigues. On a recent occasion with an alloy

I could not get the tin free from iron. The alloy only had 1.7 per cent. of iron. It was remelted copper scrap.

Mr. Menough. Did you find enough iron to materially influence the results?

Mr. Garrigues. Yes. The iron that I dissolved out with concentrated boiling hydrochloric acid, was, as far as I remember, 25 milligrams, working on 5 grams of the sample.

Mr. McKenna. Did you use fuming nitric acid?

Mr. Garrigues. No. In the method called Bounte's method, I think you use fuming nitric acid.

Mr. McKenna. Nitric acid of 1.60 sp. gr. does not act on the alloy until you add 3 c. c. of water. The tin separates out much freer from iron than the old way and is practically pure. The fuming acid will dissolve a sample containing large lumps in less than five minutes.

Prof. Phillips. speaking of the Gooch crucible: I have been using a method somewhat like that, although it is probably not so good as the Gooch crucible for many purposes. I used a very short chloride of calcium tube, about $\frac{3}{4}$ or 1 inch wide, then a bulb, then a little narrow end, probably three-sixteenths of an inch wide; the whole thing is about three and one-half inches long. Lay asbestos fibres in that obliquely so that they take a curved shape, and crossing each other. You can make a great many determinations, and can dry the precipitates very quickly by passing a stream of natural gas through. I have used that method for determining sulphide of lead. Passing dried natural gas through the chloride of calcium tube in a drying oven will dry out sulphide of lead very quickly. Of course you cannot weigh sulphide of lead very easily, drying it in the ordinary way, on account of its oxidation. There is no oxigen in our natural gas, and you can get the sulphide of lead ready for weighing very quickly. I think there are more uses for natural gas in analytical chemistry than often imagined. It seems to me that we use it for so many purposes that I do not know how we could get along without it. I noticed

that at Middletown hydrogen gas was being used for the purpose of drying organic substances for analysis, purifying the hydrogen in a drying oven. All the hydrogen had to be prepared, and a very ingenious automatic generator is being used. I could not help thinking that we could go one better with our natural gas without any drying at all; in fact, some of our natural gas is almost dry enough to use without any artificial drying: it contains so little moisture that a chloride of calcium tube will answer for an almost immeasurable volume of gas.

The CHAIRMAN: Is there not danger when the pumps are put on that some air might be sucked through the joints?

PROF. PHILLIPS: I suppose that might happen, but I have always found the gas free from oxygen.

MR. WILKINS (to Mr. Garrigues): Do you use anything to keep the air from your standard alkali solutions?

MR. GARRIGUES: I use 25° Beaune, neutral, "Zone" paraffine oil.

PROF. PHILLIPS: Natural gas may be used for the same purpose. Keep the bottles on a shelf, closed with a double perforated stopper. One hole carries the syphon and the other a glass tube connected with the gas supply, with a small tube containing alkali between the two. That is a good way to keep oxygen out of standard stannous chloride solution.

MR. GARRIGUES: A great advantage in making up soda solution in the way described is in not having any barium in it. Very frequently you want to determine the acidity of a solution and then use it for some other purpose. If it contains any sulphates the small excess of barium in your standard alkali will give a precipitate which has to be removed before you can do anything with your other determinations.

MR. MCKENNA: It seems strange to me that the last traces of carbonate separates out.

MR. GARRIGUES: I did not discover it accidentally. I just came to the conclusion that it could not help but do that, and then tried it with the above result. It simply depends, I

think, on the greater solubility of the caustic soda. The solution becomes saturated with caustic soda to the exclusion of carbonate of soda, which is the less soluble.

Mr. McKenna: It certainly is not a general law that the presence of one salt diminishes the solvent action of the solution on another salt. However, the fact is just as important, It would be a convenient way to make up the solution.

Prof. Phillips: There are some cases of that kind.

Mr. Garrigues: I am willing to stand by it that this is one of those cases. Suppose you could keep the solution cool so that it would not become supersaturated, or supposing you added alkali to water in small quantities, I do not know whether you would crowd sodium carbonate out, but when you get a hot saturated solution it is bound to drop something when it gets cool.

Mr. McKenna: It would drop both of them in proportion to the amounts dissolved.

Mr. Garrigues: I think I shall try that on some other salts.

The Chairman: How much water would you add to get the conditions you mentioned?

Mr. Garrigues: I never measured it. I simply take the bottle I get it in which contains a pound, and fill it with water.

Adjourned at 10 P. M.

A. D. Wilkins,
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Mch,	'84.	Brashear, John A.,	260 Perrysville Ave., Allegheny, Pa.
Feb.,	'91.	Branne, J. G.,	No. 23 Sondse Gade, Trondhjens, Norway, Europe.
Jan.,	'80.	Browne, Geo. H.,	Westinghouse Bldg, Pittsburg, Pa.
Feb.,	'96.	Brown, C. S.,	City Hall, Allegheny, Pa.
Apr,	'93.	Brown, A. F.,	40th St., Pittsburg, Pa.
Jan.,	'80.	Brown, W. R.,	City Engineer's Office, Pittsburg, Pa.
Mar.,	'92.	Brynn, P.,	Shiffler Bridge Co., Pittsburg, Pa.
Mar.,	'94.	Bryan, Chas. W.,	Wilmington, Del.

Date of Membership.			
Jan.,	'87.	Buente, C. F.,	Perrysville Ave, nr. Charles St, Allegheny, Pa.
Jan.,	'86.	Cadman, A. W.,	63 Water St, Pittsburg, Pa.
May,	'82.	Camp, Jas. M.,	Duquesne Steel Works, Duquesne, Pa.
June,	'92.	Card, W. W.,	Penn and Murtland Aves. Pittsburg, Pa.
Feb.,	'83.	Carhart, Daniel,	1312 Centre St., Stat. "D.," Pittsburg, Pa.
Nov.,	'84.	Carlin, David,	West Market St., Allegheny, Pa.
May,	'85.	Carlin, Thos. H.,	181 Robinson St., Allegheny, Pa.
Dec.,	'90.	Carnahan, R. B, Jr.,	W. Dewees Wood Co., McKeesport, Pa.
Apr.,	'90.	Carnegie, Andrew,	5 West 51st St., New York, N. Y.
Sept.,	'83.	Chambers, J. S., Jr.,	19 Church Ave, Allegheny, Pa.
Feb.,	'80.	Chess, H B.,	531 Wood St., Pittsburg, Pa.
Nov.,	'82.	Clapp, Geo. H.,	The Pittsburg Reduction Co, 325 Water St., Pittsburg, Pa.
Apr.,	'92.	Clifton, W. R.,	Shenango Valley Steel Co., New Castle, Lawrence Co., Pa.
Oct.,	'83.	Coffin, W. C., Jr.,	39 Cortlandt St., New York, N. Y.
Feb.,	'91.	Comp, C. A.,	Westinghouse Elec. Co., East Pittsburg, Pa.
May,	'91.	Connelley, C. B.,	Western University, Allegheny, Pa.
Feb.,	'81.	Cooper, Chas. A.,	410 Grant St., Pittsburg, Pa.
Apr.,	'92.	Cooper, Frank I.,	Heath Hill, Brookline, Mass.

Date of Membership.			
Nov.,	'89.	Cornelius, W. A.,	Munhall, P.V. & C. R.R., Pa.
Apr.,	'92.	Coster, Wm. H.,	4502 5th Ave , Pittsburg, Pa.
Mar.,	'92.	Crabtree, Fred.,	Monongahela Furnace Co., McKeesport, Pa.
Oct.,	'94.	Crosgrove, W. L ,	6359 Aurelia St , Pittsburg, Pa.
Sept.,	'80.	Curry, H. M.,	Treas. Carnegie Steel Co. and the H. C. Frick C. Co., Rm. 419 Carnegie Bld., Pittsburg, Pa.
Mar.,	'94.	Curtis, Frank J.,	Ben Avon, Pa.
Apr.,	'92.	Davis, Authur V.,	The Pittsburg Reduction Co., 325 Water St., Pittsburg, Pa.
Jan.,	'80.	Davis, Charles,	County Eng., Court House, Pittsburg, Pa.
Dec.,	'80.	Davison, Geo. S.,	Westinghouse Bldg., Pittsburg, Pa.
Mar ,	'92.	Davison, N. C.,	68 Water St , Pittsburg, Pa.
Feb.,	'91.	Deforth, J. M.,	Keystone Bridge Wks., Pittsburg, Pa.
Jan.,	'80.	Demptser, Alex ,	40 7th Ave , Pittsburg, Pa.
Jan.,	'80.	Diescher, Samuel,	Hamilton Bldg., Pittsburg, Pa.
Nov.,	'87.	Dobson, T. H.,	Penn P. O , Lancaster Co., Pa.
Nov.,	'90.	Doxrud, Peter,	P. O. Box No. 832, Pittsburg, Pa.
Oct ,	'90.	Dravo, E T.,	49 Fifth Ave , Pittsburg, Pa.
Jan ,	'92.	Driver, C. M.,	P. O. Box 541, Pittsburg, Pa.
Oct.,	'93.	Drozdov, A. Z.,	Care of Penn'a. Steel Co., Steelton, Pa.

Date of Membership.			
Dec.,	'92.	Dubbs, Jesse A.,	Rm. 52 Bakewell Law Bldg., Pittsburg, Pa.
Mar.,	'92.	Duckham, A. E.,	232 Rebecca St., E. E., Pittsburg, Pa.
Apr.,	'92.	Dudley, C. B.,	Ph. D., Altoona, Pa.
Mar.,	'93	East, Wm. J.,	Westinghouse Bldg., Pittsburg, Pa.
Jan.,	'81.	Eckert, E. W.,	1313 Monadnock Bldg., Chicago, Ill.
Jan.,	'80.	Edeburn, W. A.,	410 Grant St., Pittsburg, Pa.
Feb.,	'88.	Engle, Geo. U.,	131 East Third St., Newport, Ky.
Sept.,	'82.	Engstrom, Frans,	Highland Park Pittsburg, Pa.
Feb.,	'88.	Estrada, E. D.,	307 Lewis Block, Pittsburg, Pa.
Mar.,	'93.	Evans, Rawdon,	Bank of Commerce Bldg., Pittsburg, Pa.
Feb.,	'92.	Farrar, Chas. J.,	Rm. 714 Lewis Blk., Pittsburg, Pa.
Apr.,	'92.	Faunce, Geo.,	Carnegie, Pa.
Mar.,	'86.	Ferris, G. W. G.,	P. O. Box 539, Pittsburg, Pa.
June,	'94	Fessenden, R. A.,	Chas. St. nr. Perrysville Ave., Allegheny, Pa.
Jan.,	'95.	Fisher, Henry W.,	Standard Underground Cable Co., 16th and Pike Sts., Pittsburg, Pa.
Dec.,	'95.	Fischer, Fred. F.,	Robinson St., near 5th Ave., Pittsburg, Pa.
Jan.,	'85.	Fitler, F. K.,	327 Water St., Pittsburg, Pa.
May,	'94.	Flack, Chas. A.,	Logan's Ferry, Allegheny Co., Pa.

Date of Membership.			
Jan.,	'96.	Fitzgerald, Chas.,	155 44th St., Pittsburg, Pa.
Feb.,	'96.	Fulton, David L.,	287 Federal St., Allegheny, Pa.
Jan.,	'96.	Fawcus, Thos.,	McKee's Rocks, Pa.
June,	'94.	Flanagan, G. E.,	Care Hydraulic Machine Co., 54th St., Pittsburg, Pa.
Apr.,	'91.	Forter, S.,	Mackintosh, Hemphill & Co., Pittsburg, Pa.
Feb.,	'82.	Frank, Isaac W.,	54th St. and A. V. R. R., Pittsburg, Pa.
Apr.,	'93.	Friend, Chas. W.,	14 Lincoln Ave., Allegheny, Pa.
Jan.,	'80.	Frost, A. E.,	Western University, Allegheny, Pa.
Apr.,	'88.	Fulton, Louis B.,	34 Penn Ave., Pittsburg, Pa.
May,	'95.	Garrigues, W. E.,	Care Duquesne Chemical Laboratory, 312 4th Ave., Pittsburg, Pa.
Oct.,	'83.	Glafey, Fred'k. A.,	Rm. 1315 Carnegie Bldg., Pittsburg, Pa.
Mar.,	'92.	Glass, G. G.,	La Belle Steel Works, Allegheny, Pa.
Nov.,	'94.	Goldie, William,	Station "D," Pittsburg, Pa.
Feb.,	'80.	Goodyear, S. W.,	Waterbury, Conn.
Jan.,	'95.	Gow, Alex'r. M.,	Wyandotte, Mich.
Feb.,	'94.	Grafton, W. McC.,	Penn'a. Co.'s Bldg., Penn Ave., Pittsburg, Pa.
May,	'92.	Graham, Neville B.,	Duquesne, Pa.
June,	'85.	Grant, Horace E.,	116 Cliff St., Pittsburg, Pa.
Oct.,	'92.	Greenwood, G. F.,	Rm. 23 Vandergrift Bldg., Pittsburg, Pa.
Jan.,	'92.	Griffen, Francis A.,	319 S. Highland Ave., E. E., Pittsburg, Pa.
Sept.,	'82.	Gwinner, Fred., Jr.,	Allegheny, Pa.

Date of Membership.			
Mar.,	'83.	Hackett, Geo. W.,	1009 Liberty St., Pittsburg, Pa.
Dec.,	'90.	Hall, Chas. M.,	Care Pittsburg Reduction Co., Room 701 Ferguson Blk., Pittsburg, Pa.
Feb.,	'91.	Hallgren, Emil,	517 Euclid Ave., E. E., Pittsburg, Pa.
Feb.,	'91.	Hardie, J. B.,	Keystone Bridge Works, Pittsburg, Pa.
April,	'81.	Harlow, Geo. R.,	Station "D", Pittsburg, Pa.
Jan.,	'80.	Harlow, Jas. H.,	Station "D", Pittsburg, Pa.
March,	'92.	Harrison, A. B.,	7 LaBelle St., S. S., Pittsburg, Pa.
Nov.,	'91.	Hartrick, R. S. D.,	134 Water Street, Pittsburg, Pa.
Feb.,	'93.	Hays, Jos. A.,	Care Chas. Roome, Parmele Co., Manufac'ing Chemists, 98 William St., New York, N. Y.
Oct.,	'92.	Hays, Wm. H.,	32d and Smallman Sts., Pittsburg, Pa.
Jan.,	'80.	Hemphill, Jas.,	Mackintosh, Hemphill & Co., Pittsburg, Pa.
April,	'93.	Henry, Wm D.,	8th Floor, Carnegie Bldg., Pittsburg, Pa.
Nov.,	'85.	Heron, Fred.,	Supt. Phœnix Iron Works, Phœnixville, Pa.
Oct.,	'92.	Herron, W. A.,	406 Wood St., Pittsburg, Pa.
Jan.,	'86.	Hetzel, Jas.,	Western University, Allegheny, Pa.
Dec.,	'94.	Hirsch, Richard,	1318 Fifth Ave., Pittsburg, Pa.
Nov.,	'88.	Hoag, I. V., Jr.,	170 South Ave., Allegheny, Pa.

Date of Membership.		
March, '94.	Holmes, A. G.,	Care Fuel, Gas & Mfg. Co., Brinton Sta., P. R. R., Pa.
April, '80.	Hoffstot, F. N.,	Water St., Pittsburg, Pa.
Sept., '88.	Hohl, L. I.,	100 Boggs Ave., Pittsburg, Pa.
Dec., '88.	Holland, W. J.,	Fifth Ave., Oakland, Pittsburg, Pa.
Apr., '92.	Hope, J. A. P.,	E. Winter Co., Herr's Island, Pa.
March, '92.	House, Frank E.,	P. & L. E. R. R., Beaver, Pa.
Dec., '95.	Huber, S. V.,	827 Euclid Ave., E. E., Pittsburg, Pa.
Oct., '81.	Hunt, Capt. A. E.,	Ferguson Block, Room 701, Care Pbg. Reduction Co., Pittsburg, Pa.
June, '93.	Hussey, C. G.,	347 5th Ave., Pittsburg, Pa.
Oct., '87.	Hyde, C.,	Room 902, Lewis Block, Pittsburg, Pa.
Sept., '93.	Jamison, W. W.,	Greensburg, Pa.
Dec., '88.	Jenkins, J. B.,	103 4th Ave., Pittsburg, Pa.
Feb., '81.	Jennings, B. F.,	Preble Ave., Allegheny, Pa.
April, '92.	Johnson, C. M ,	Box 101, Avalon, Pa.
Jan., '88.	Johnson, Thos. H.,	Penn'a Lines, 10th St. & Penn Ave , Pittsburg, Pa.
May, '92.	Johnston, J. P.,	Room 1014 Carnegie Bldg., Pittsburg, Pa.
April, '95.	Johnson, Dr. E. S.	Black Diamond Steel Wks., 30th St., Pittsburg, Pa
April, '81.	Jones B. F.,	Jones & Laughlin, Ltd., Pittsburg, Pa.
March, '88.	Jones, W. Larimer,	Jones & Laughlin, Ltd., Pittsburg, Pa.
Nov. '80.	Kaufman, Gustave,	812 Hamilton Building, Pittsburg, Pa.

Date of Membership.		
Feb., '85.	Kay, Jas. I.,	96 Diamond St., Pittsburg, Pa.
March, '85.	Kelly, J. A.,	28th and Smallman Sts., Pittsburg, Pa.
Jan., '85.	Kelly, J. W.,	Box 44, New Brighton, Pa.
Oct., '91.	Kelly, M. B.,	61 Wylie Ave., Pittsburg, Pa.
April, '92.	Kemery, Philo,	Crescent Steel Works, 51st & A. V. Ry., Pittsburg, Pa.
Feb., '91.	Kemler, W. H.,	Ashland, Ky.
May, '86.	Kennedy, Julian,	Room 78, Vandergrift Bldg., Pittsburg, Pa.
Dec., '95.	Klingelhofer, G. E.,	5515 Howe St., E. E., Pittsburg, Pa.
Sept., '82.	Kenyon, L. H.,	Pittsburg Locomotive Wks., 396 Beaver Ave., Allegheny, Pa.
June, '88.	Kimball, Frank I.,	Greensburg, Pa.
Feb., '82.	King, T. M.,	Office of the 2d Vice-Prest. B. & O. R. R., Baltimore, Md.
March, '82.	Kirk, Arthur,	care David M. Kirk, P. O. Box 275, Pittsburg, Pa.
Nov., '87.	Kirtland, A. P.	Room 1206, Carnegie Bldg., Pittsburg, Pa.
March, '95.	Keller, C.,	Station "D", Pittsburg, Pa.
April, '95.	Keller, E. E.,	224 Murtland Ave., E. E., Pittsburg, Pa.
April, '87.	Koch, Walter E.,	The Spang Iron & Steel Co., Sharpsburg, Pa.
March, '92.	Kuntz, J. F.,	Wilkins and Davison, Pittsburg, Pa.
Feb., '92.	Lamb, Geo.,	121 Maryland Ave., N. E., Washington, D. C.

Date of Membership.			
Feb.,	'96.	Langenheim, G. C.,	City Engineer's Office, Allegheny, Pa.
Nov.,	'88.	Langley, J. W.,	845½ Fairmount St., Cleveland, O.
Oct.,	'92.	Lash, Horace W.,	Carbon Steel Co., Pittsburg, Pa.
May,	'85.	Lauder, Geo.,	Room 325 Carnegie Building, Pittsburg, Pa.
Feb.,	'93.	Laughlin, Alex.,	Lewis Block, Pittsburg, Pa.
April,	'84.	Leishman, J. G. A.,	Carnegie Buildg., Room 312, Pittsburg, Pa.
March,	'80.	Lewis, John L.,	Lewis Foundry and Machine Co., Ltd., S.S., Pittsburg, Pa.
May,	'90.	Lewis, Harry J.,	Times Buldng., Pittsburg, Pa.
Nov.,	'94.	Linton, Robt.,	Care Schmertz Glass Co, Bellevernon, Fayette Co., Pa.
Sept.,	'84.	Lloyd, Henry,	Care Linden Steel Co., Pittsburg, Pa.
April,	'92.	Lœffler, Geo. O.,	Care Carbon Steel Co., 32d and Smallman Sts., Pittsburg, Pa.
March,	'94.	Loomis, DeWayne,	Crafton, Pa.
Sept.,	'90.	Ludwig, Jos.,	525 State St., Schenectady, N. Y.
Feb.,	'92.	Liggett, D. S.,	Fair Play P. O., Jefferson Co., O., P. C. C. & St. L. R. R.
March,	'92.	Lyons, Jas. K.,	2126 Webster Ave, Pittsburg, Pa.
March,	'93.	Lynne, Mary L.,	4621 Forbes St., E. E., Pittsburg, Pa.
Jan,	'80.	Macbeth, Geo. A.,	Telephone Building, Room 311, 7th Ave., Pittsburg, Pa.

Date of Membership.		
Jan., '96.	Mathisen, Christen,	1310 Carnegie Building, Pittsburg, Pa.
Nov., '92.	Mackenzie, Jas.,	Carnegie Building, Room 1418, Pittsburg, Pa.
April, '81.	Malone, M. L.,	320 Fifth Ave., Pittsburg, Pa.
Jan., '80.	Martin, Wm.,	P. O. Box 670, Pittsburg, Pa.
March, '92.	Manning, W. T.,	Office of the Chief Engineer B. & O. R. R., Baltimore, Md.
Dec., '92.	van Marken, J. C.,	98 L. V Meerdervoort, The Hague, Holland.
April, '92.	Marsh, Geo. A.,	Carnegie, Pa.
Dec., '83.	Mead, Edward,	142 West Main St., Louisville, Ky.
Feb., '91.	Means, E. C.,	Westinghouse Electric Co., East Pittsburg, Pa.
Dec., '92.	Menough, H. S.,	West Penn Steel Works, Allegheny, Pa.
Sept., '90.	Mercader, Camille,	Edgar Thomson Steel Wks., Braddock, Pa.
March, '88.	Mesta, Geo.,	Lewis Block, Room 512, Pittsburg, Pa.
Jan., '80.	Metcalf, Wm.,	136 1st Ave., Pittsburg, Pa.
Jan., '84.	Meyran, L. A.,	Rooms 406-409, Germania Savings Bank Building, Pittsburg, Pa.
Feb., '82.	Milholland, J. B.,	5th Ave. and Tunnel St., Pittsburg, Pa.
March, '93.	Miller, H. B.,	Duquesne Steel Works, Duquesne, Pa.
May, '85.	Miller, Wilson,	18 Lincoln Ave., Allegheny, Pa.

Date of Membership.		
Oct., '80	Milliken, A C.,	Pottsville Iron & Steel Co., Pottsville, Pa.
April, '92.	Mixer, Chas. T.,	600 E. High St., Ishpeming, Mich.
March, '92.	Mollenauer, F. H.,	Castle Shannon, Pa.
March, '92.	Moorhead, J. K.,	104-106 Grant St., Pittsburg, Pa.
April, '81.	Moorhead, M. K ,	8 Wood St., Room 29, Pittsburg, Pa.
Oct., '86.	Morris, G. W.,	P. O. Box 656, Pittsburg, Pa.
Jan., '90.	Morris, A. S.,	Westinghouse Elec. Co , East Pittsburg, Pa.
Apr., '93.	Morrison, Thos.,	Braddock, Pa.
Jan , '96.	Morse, E. K ,	Rm. 1206 Carnegie Bldg , Pittsburg, Pa.
Mar., '90.	Mueller, Gustave,	Care of Duquesne Chemical Laboratory, 312 4th Ave., Pittsburg, Pa.
Apr., '80.	Munroe, Robert,	23d and Smallman Sts., Pittsburg, Pa.
Sept , '92.	Muse, W. G.,	West Newton, Pa.
Apr., '92.	Myers, U. H ,	34 Anderson St., Allegheny, Pa.
Jan., '91.	McClintock, H. P.,	South Ave. and Snowden St , Allegheny, Pa.
Oct , '92.	McClintic, H. H.,	Shifller Bridge Works, Pittsburg, Pa.
May, '85.	McConnell, J. A.,	Rm. 24 Schmertz Bldg., 203 Water St , Pittsburg, Pa
Mar., '81.	McCully, R. L.,	161 5th Ave., Pittsburg, Pa.
May, '89.	McDonald, John,	Pittsburg Foundry Machine Co., L't'd, 32nd St. and Penn Ave , Pittsburg, Pa.

Date of Membership.		Name	Address
Dec.,	'89.	McDonald, C. I.,	143 Fayette St., Allegheny, Pa.
Mar.,	'93.	McDonald, T. M.,	Care The Ohio Steel Co., Youngstown, O.
Mar.,	'92.	McGary, Daniel,	Care Painter & Sons' Co., Pittsburg, Pa.
April,	'94.	McGrew, Anson B.,	Rm. 714 Lewis Block, Pittsburg, Pa.
Jan.,	'91.	McKaig, Thos. B.,	Ferguson Bldg., Pittsburg, Pa.
Mar.,	'92.	McKelvy, J. P.,	Mackintosh, Hemphill & Co., Pittsburg, Pa.
Apr.,	'95.	McClelland, E. S.,	Westinghouse Machine Co., 25th St. and Liberty Ave., Pittsburg, Pa.
Mar ,	'95.	McDonald, F. A ,	Rms. 811-813 Penn Bldg., Pittsburg, Pa.
Apr.,	'92.	McKenna, A. G.,	Care Sterling Steel Co., Demmler, Pa.
Sept.,	'80.	McKinney, J. P.,	141 Fayette St., Allegheny, Pa.
Feb.,	'82.	McMurtry, G. G.,	Apollo Iron & Steel Co., Pittsburg, Pa.
Feb.,	'85.	McQuiston, Jas ,	26th and Railroad Sts., Pittsburg, Pa.
Mar ,	'81.	McRoberts, J. H.,	400 Grant St., Pittsburg, Pa.
Jan.,	'80.	Naegeley, John,	311 Hamilton Bldg , Pittsburg, Pa.
Dec.,	'92.	Neale, John C.,	39 Cortlandt St., New York.
May,	'94.	Neeland, Marvin A.,	Duquesne, Pa.
Nov.,	'91.	Nichols, Chas. H.,	39 Cortlandt St., New York, N. Y.
Jan.,	'80.	Nichols, T. B.,	Plattsburgh, N. Y.

Date of Membership.			
Mar.,	'92.	Nicholson, J. H.,	Rm. 615 Times Bldg., Pittsburg, Pa.
Apr.,	'80.	Nimick, F. B,	Singer, Nimick & Co., L't'd., Pittsburg, Pa.
Feb,	'82.	Noble, Patrick,	200 Market St., San Francisco, Cal.
Nov.,	'92.	Nurick, Alex.,	Jones & Laughlin, L't'd., South Side, Pittsburg, Pa.
Nov.,	'92.	Oakley, Frank T.,	Engineering Dept. T. A. A. & N. M. Ry., Toledo, O.
Mar.,	'92.	Opsion, Ole C.,	Shiffler Bridge Co., Pittsburg, Pa.
Nov.,	'92.	Page, Geo. S.,	6710 McPherson St., E. E., Pittsburg, Pa.
Mar.,	'84.	Painter, Park,	245 Ridge Ave., Allegheny, Pa.
Nov.,	'88.	Palmer, W. P.,	37 Beech St., Allegheny, Pa.
Jan.,	'80.	Parkin, Chas.,	Parnassus, Pa.
April,	'84.	Parkin, W. F.,	136 1st Ave., Pittsburg, Pa.
Dec.,	'91.	Parsons, B. H,	Edward Corning & Co., 29 Broadway, New York, N. Y.
May,	'94.	Patterson, F. W.,	Nat'l. Bank Bldg. of McKeesport, McKeesport, Pa.
Mar.,	'92.	Patterson, P. C.,	McKeesport, Pa.
Feb.,	'81.	Patterson, Peter,	National Tube Works, McKeesport, Pa.
Jan.,	'80.	Phillips, F. C.,	Western University, Allegheny, Pa.
Dec.,	'88.	Purves, Jas.,	Pineville, Ky.
Jan.,	'83.	Phipps, Henry, Jr.,	Rm. 325 Carnegie Bldg., Pittsburg, Pa.
Mar.,	'92.	Pierce, Chas. I.,	Western Tube Co., Kewanee, Ill.

Date of Membership.			
Oct.,	'93.	Le Pontois, Leon,	Westinghouse E. & M. Co., East Pittsburg, Pa.
Dec.,	'81.	Porter, John C.,	Spang Steel and Iron Co., Etna, West Penn R. R.
May,	'87.	Porter, John E.,	Penn Ave. and 2nd St., Pittsburg, Pa.
Jan.,	'83.	Prentice, W. J.,	1009 Liberty St., Pittsburg, Pa.
Dec.,	'90.	Randolph, Alfred,	113 Depot St., Salem, Ohio.
June,	'93.	Reed, Hugh A.,	212 Lacock St., Allegheny, Pa.
Jan.,	'80.	Rees, Thos. M.,	J. Rees & Sons, Pittsburg, Pa.
May,	'83.	Reno, Geo. E.,	Care Reno & Johns, 306 4th Ave., Pittsburg, Pa.
Jan.,	'80.	Rhodes, Joshua,	Penn'a. Tube Works, Pittsburg, Pa.
Jan.,	'80.	Ricketson, J. H.,	A. Garrison Foundry Co., 10 and 12 Wood St., Pittsburg, Pa.
Jan.,	'92.	Riddle, Walther,	287 Ridge Ave., Allegheny, Pa.
Oct,	'95.	Rites, F. M.,	Edgewood Park, P. R. R., Pittsburg, Pa.
Jan.,	'88.	Robbins, F. L.,	Penn Bldg., Pittsburg, Pa.
Jan.,	'80.	Roberts, Thos. P.,	Rm. 25 Iron Exchange Bldg., Wood St., Pittsburg, Pa.
Jan.,	'80.	Rodd, Thos.,	Penn'a. Co., 10th St. and Penn Ave, Pittsburg, Pa.
Nov.,	'92.	Rousseau, H. H.,	Pittsburg Bridge Co., 36th St. & A. V. R. R., Pittsburg, Pa.
Nov.,	'89.	Ruhe, C. H. W.,	1423 Bluff St, Pittsburg, Pa.

Date of Membership.			
Jan.,	'88.	Ruud, Edwin,	Fuel-Gas and Mfg. Co., Brinton Sta., P. R. R., Pa.
Apr.,	'84.	Scaife, O. P.,	421 Wood St., Pittsburg, Pa.
Mar.,	'83.	Scaife, W. Lucien,	28th and Smallman Sts., Pittsburg, Pa.
Sept.,	'87.	Scaife, W. M.,	336 Ridge Ave., Allegheny, Pa.
Feb.,	'82.	Schellenberg, F. Z.,	159 1st Ave., Pittsburg, Pa.
Jan.,	'80.	Schinneller, Jacob,	Rm. 31 McClintock Block, Pittsburg, Pa.
Feb.,	'85.	Schmid, Albert,	Westinghouse E. & M. Co., East Pittsburg, Pa.
May,	'83.	Shook, Levi,	1st Ave., and Ferry St., Pittsburg, Pa.
Feb.,	'94.	Schoyer, A. M.,	Library Place, Allegheny, Pa.
Mar.,	'92.	Schluederberg, G. W.,	374 Ridge Ave., Allegheny, Pa.
Sept.,	'92.	Schade, C. G.,	96 43rd St., Pittsburg, Pa.
Nov.,	'85.	Schultz, O. G.,	Box 65, McKee's Rocks, Pa.
Nov.,	'81.	Schwartz, F. H.,	5000 Liberty Avenue, Pittsburg, Pa.
Mar.,	'84.	Schwartz, J. E.,	P. O. Box 594, Pittsburg, Pa.
April,	'90.	Scott, Chas F.,	Westinghouse E. & M. Co., East Pittsburg, Pa.
Feb.,	'92.	Scott, Jas.,	Lucy Furnace Co., Pittsburg, Pa.
Jan.,	'89.	Shaw, A. G.,	County Engineer's Office, Pittsburg, Pa.
May,	'94.	Shaw, H. C.,	Lewis Foundry Machine Co., South Side, Pittsburg, Pa.
Jan.,	'89.	Shaw, W. W.,	County Engineer's Office, Pittsburg, Pa.
Sept.,	'80.	Singer, G. H.,	83 Water St., Pittsburg, Pa.

Date of Membership.			
May,	'90.	Singer, R. R.,	Singer Bldg., 331 4th Ave., Pittsburg, Pa.
Sept.,	'80.	Singer, W. H.,	Singer, Nimick & Co., Ltd., Pittsburg, Pa.
April,	'92.	Slocum, F. S.,	Care Jones & Laughlins, Ltd., Pittsburg, Pa.
Mar.,	'93.	Smiley, W. P.,	Penn'a. State College, State College, Pa.
Jan.,	'90.	Smith, F. S.,	Westinghouse E. & M. Co., Foundry Dept., Lamp Factory, Robinson St., Allegheny, Pa.
Feb.,	'80.	Snyder, Antes,	Eng. Right of Way, P. R. R., Blairsville, Indiana Co., Pa.
Oct.,	'92.	Snyder, Chris. H.,	Care Milliken Bros., 39 Cortlandt St., New York, N.Y.
April,	'84.	Snyder, W. P.,	German Natl. Bank Bldg., Pittsburg, Pa.
Dec.,	'94.	Speer, James R.,	Shoenberger, Speer & Co., Pittsburg, Pa.
May,	'81.	Stafford, C. E.,	Shoenberger & Co., Pittsburg, Pa.
April,	'93.	Stafford, Sam'l. G.,	516 Market St., Pittsburg, Pa.
May,	'83.	Stevenson, D. A.,	Box 308, Pittsburg, Pa.
Jan.,	'86.	Stevenson, W. S.,	Fairmont, W. Va.
April,	'92.	Stahl, Carl F.,	57th St. and A. V. R. R., Pittsburg, Pa.
Oct.,	'86.	Stewart, J. A.,	Care Humphreys, Stewart & Co., Rm. 712 Lewis Block, Pittsburg, Pa.
Dec.,	'94.	Stewart, Reid T.,	Western University of Pa., Allegheny, Pa.

Date of Membership.			
Jan.,	'90.	Stillwell, L. B.,	Westinghouse Electric Co., East Pittsburg, Pa.
Jan.,	'80.	Stillburg, J. H.,	20 5th Ave., Pittsburg, Pa.
Feb.,	'96.	Strauss, H. A.,	Westinghouse E. & M. Co., East Pittsburg, Pa.
Feb.,	'96.	Stulen, J. C.,	268 Fisk St., Pittsburg, Pa.
Feb.,	'83.	Swan, Robert,	34 Ohio St., Allegheny, Pa.
Feb.,	'95.	Strunz, F. B.,	708 Bingham St., Pittsburg, Pa.
Feb.,	'91.	Stupakoff, S. H.,	U. S. & S. Co., Swissvale, Pa.
April,	'87.	Swensson, Emil,	Keystone Bridge Works, Pittsburg, Pa.
Mar.,	'92.	Sivertsen, O.,	The Stirling Company, Barberton Inn, Barberton, Ohio.
Dec.,	'92.	Sutton, Stansbury,	220 Western Ave., Allegheny, Pa.
Oct.,	'91.	Tallman, F. G.,	Rm. 1112 Carnegie Bldg., Pittsburg, Pa.
April,	'80.	Taylor, E. B.,	1003 Penn Ave., Pittsburg, Pa.
Feb.,	'84.	Taylor, B. H.,	Edgar Thomson Steel Works, Braddock, Pa.
Mar.,	'92.	Taylor, Selwyn M.,	420 Bissell Block, Pittsburg, Pa.
Dec.,	'90.	Temple, W. C.,	408 Lewis Block, Pittsburg, Pa.
May,	'86.	Tener, Geo. E.,	Edith Furnace Co., Allegheny, Pa.
April,	'92.	Thomas, Wm. A.,	Thomas Furnace Co., Niles, O.
April,	'89.	Thorsell, J. A.,	119 1st Ave., Pittsburg, Pa.
Mar.,	'92.	Townsend, C. W.,	81 Westinghouse Bldg., Pittsburg, Pa.

Date of Membership.			
Mar.,	'91.	Tone, S. LaRue,	108 4th Ave., Pittsburg, Pa.
Dec.,	'90.	Tonnele, Theo.,	McKeesport, Pa.
Jan.,	'80.	Trimble, Robert,	Penn'a. Co., 10th St. and Penn Ave., Pittsburg, Pa
Sept.,	'93.	Turner, C. A. P.,	Care Pottsville Iron and Steel Co., Pottsville, Pa.
		Thompson, Benj.,	Care Southern Railway Co., Greensboro, Guilford County, N. C.
May,	'93.	Urquhart, Geo. C.,	Rm. 609, 1003 Penn Ave., Pittsburg, Pa.
Feb,	'81.	Utley, Edwd. H.,	Rm. 414 Carnegie Bldg., Pittsburg, Pa.
Feb.,	'96.	Unger, J. S.,	Carnegie Steel Co., P. V. & C. R. R., Munhall, Pa.
Feb.,	'92.	Vandivort, Theo.,	Blairsville, Indiana Co., Pa.
June,	'93.	Veeder, Herman,	Rm. 606 Times Bldg., Pittsburg, Pa.
May,	'85.	Verner, M. S.,	Supt. Citizens' Traction Co., Rm. 808 Penn Bldg., Pittsburg, Pa.
Dec.,	'92.	Vierheller, Ph.,	Keystone Bridge Works, Pittsburg, Pa.
Mar.,	'95.	Wackermann, F.,	2109 Wharton St., S. S., Pittsburg, Pa.
April,	'93.	Wagner, Karl von,	McKee's Rocks, Pa.
April,	'82.	Wainwright, J.,	Rm. 42 Conestoga Bldg., Pittsburg, Pa.
Jan.,	'80.	Walker, J. W.,	240 44th St., Pittsburg, Pa.
Dec.,	'91.	Walker, Robt. L.,	Library Place, Allegheny, Pa.
Jan.,	'83.	Warden, C. F.,	7 Shetland Ave., Pittsburg, Pa.

Date of Membership.			
April,	'87.	Weiskopf, S. C.,	1245 Madison Ave., New York, N. Y.
May,	'94.	Weldin, Lewis C.,	Rm. 7 Union Station, P. R. R., Pittsburg, Pa.
April,	'92.	Wendt, E. F.,	P. & L. E. R. R., New Brighton, Pa.
May,	'92.	White, F. L.,	4616 Plummer St., Pittsburg, Pa.
May,	'83.	White, T. S.,	Beaver Falls, Pa.
Nov.,	'94.	White, W. G.,	Mahoningtown P. O., Lawrence Junction, Pa.
Oct.,	'90.	Wieland, C. F.,	Edwardsville, Ill.
Feb.,	'80.	Wightman, D. A.,	154 Locust St., Allegheny, Pa.
Jan.,	'94.	Wilcox, Frank,	T. A. & R. G. Gillespie, 31 Westinghouse Bldg., Pittsburg, Pa.
Jan.,	'90.	Wilcox, John F.,	Lewis Block, Pittsburg, Pa.
Feb.,	'93.	Wilkins, A. D.,	Care Locomotive Works, 396 Beaver Ave., Allegheny, Pa.
May,	'87.	Wilkins, W. G.,	Westinghouse Bldg., Pittsburg, Pa.
April,	'93.	Williams, Chauncey G.,	11th and Pike Sts., Pittsburg, Pa.
April,	'92.	Williams, John E.,	Box 177, Crafton, Pa.
April,	'92.	Williams, Fred. H.,	Riverside Iron Works, Wheeling, W. Va.
Jan,	'86.	Wilson, H. M.,	Grant Ave., Allegheny, Pa.
Jan.,	'88.	Wilson, F. T.,	Jersey Shore, Lycoming Co., Pa.
April,	'92.	Wilson, Jos. M.,	N. 3rd St, Steubenville, O.
Nov.,	'94.	Wolf, T. Frank,	Irwin, Pa.

Date of Membership.		
Sept., '80.	Wood, Rich'd. G.,	W. Dewees Wood Co., McKeesport, Pa.
Jan., '88.	Wood, Jos.,	Gen'l. Manager Pa. Lines, 1003 Penn Ave., Pittsburg, Pa.
April, '92.	Wood, E. F.,	P. V. & C. R. R., Munhall, Pa.
Jan., '88.	Woods, L. G.,	Rm. 505 McKnight & Victory Bldg., 413 4th Ave., Pittsburg, Pa.

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American Inst. Electrical Engineers,
1009 Havemeyer Bldg., 26 Cortlandt St., N. Y.
American Institute of Mining Engineers,
Lock Box 223, New York.
American Journal of Railway Appliances,
411-413 Pearl St., New York.
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Associadad dos Engenheiros Civis Portuguezos,
Lisboa, Portuguezos.
Associated Engineers of Virginia,
Room 10 Terry Building, Roanoke, Va.
Association des Ingenieurs, Ecole Speciale,
Rue Plateau, Gand. (Belgium).
Association of Provincial Land Surveyors, Toronto, Canada.
Boston Society of Civil Engineers,
36 Bromfield St., Boston, Mass.

Bureau of Education, Washington, D. C.
California State Mining Bureau, San Francisco, Cal.
Canadian Society of C. E., 112 Mansfield St., Montreal, Canada.
Civil Engineers' Club of Cleveland,
Care Case Library, Cleveland, O.
Club de Engenharia, Rio de Janeiro, Brazil, S. A.
Colorado Scientific Society, Denver, Colorado.
Conn. Assoc. of Civil Engineers and Surveyors,
Birmingham, Conn.
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Drown, T. M., Lehigh University, South Bethlehem, Pa.
École d' Application du Genie Maritime, Paris, France.
Electrical Engineering, 1107 "The Rookery," Chicago, Ill.
Engineering and Mining Journal, 253 Broadway, New York.
Engineers' Club, Kansas City, Mo.
Engineers' Club of Cincinnati, Cincinnati, O.
Engineers' Club of Philadelphia,
1122 Girard St., Philadelphia, Pa.
Engineers' Club, per Col. John McLeod, Louisville, Ky.
Engineering Association of the South, Nashville, Tenn.
Engineering Department Vanderbilt University,
Nashville, Tenn.
Engineering Review, London, Eng.
E. Ingeniero Civil,
424 Corrientes, Buenos Ayres, Argentine Republic, S. A.
Engineering Mechanics, 430 Walnut St., Philadelphia, Pa.
Engineering News, Tribune Building, New York.
Engineering Record, 277 Pearl St., New York.
Fairchild, D. G., Department of Agriculture, Washington, D.C.
Franklin Institute, 18 S. Seventh St., Philadelphia, Pa.
Gordon, Henry A., Inspecting Engineer,
Wellington, New Zealand.
Gurley, Prof. Wm. F. E., State Geologist, Springfield, Ill.
Howe, Prof. M. H., Dept. of C. E., Rose Polytech. Institute,
Terre Haute, Indiana.

Indiana Society of Civil Engineers and Surveyors,
Remington, Ind.

Institution of Civil Engineers,
25 Great George St., Westminster, London, S. W.

Iowa Society of Engineers and Surveyors, Glenwood, Iowa.

Iron Age, 96–102 Reade St., New York.

Iron and Steel Institute, Victoria Mansions,
Victoria St., London, E C.

Journal of Association of Engineering Societies,
419 Locust St., Philadelphia, Pa.

Journal of Society of Arts, John St., Adelphi, London, S. W.

Library of Pennsylvania Railroad, Altoona, Pa.

Library of Second Geological Survey of Pennsylvania,
P. O. Bldg., 4th floor, Rm. 18, Philadelphia, Pa.

Library of University of Wisconsin, Madison, Wis.

Liverpool Engineering Society,
Colquit St., Liverpool, England.

London Patent Office, H. J. Allison, Librarian Patent Office Library, 28 South Hampton Buildings, Chancery Lane, London, W. C., England.

Manufacturers' Record, Baltimore, Md.

Massachusetts Institute of Technology,
Department of Civil Engineering, Boston, Mass.

Mechanical World, New Bridge St., Manchester, England.

Mendenhall, T. C.,
Worcester Polytechnic Institute, Worcester, Mass.

Merriman, Mansfield, Prof. Dept. C. E.,
Lehigh University, S. Bethlehem, Pa.

Michigan Engineering Society, Climax, Mich.

Mineral Products of the United States,
Department of the Interior, Washington, D. C.

Ohio Society of Surveyors and Civil Engineers,
Charles A. Judson, Secretary, Sandusky, O.

Paving and Municipal Engineering, Indianapolis, Ind.

Physical Review, Ithaca, N. Y.

Railway Age, 1660–1664 Monadnock Block, Chicago, Ill.
Railway Review, 818 "The Rookery," Chicago, Ill.
Rensselaer Society of Engineering, Troy, N. Y.
Revista Obras Publicas e Minas, Lisbon, Portugal.
Roadmaster and Foreman, 91–93 Jefferson St., Chicago, Ill.
School of Mines Quarterly, 41 East 49th St., N. Y.
Science Club of Portland, Portland, Oregon.
Sibley College, Cornell University, Ithaca, N. Y.
Smithsonian Institution, Washington, D. C.
Sociedad Cientifica Argentina, Buenos Ayres, S. A.
State Association of Engineers, Norwich, Conn.
State College, State College, Pa.
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Stevens' Institute of Technology, Hoboken, N. J.
Svenska Teknologföreningen, Stockholm, Sweden.
Swedish Society of Civil Engineers, Stockholm, Sweden.
Tin and Terne and The Metal World, B. E. V. Luty, Editor, Rm. 406 Ferguson Block, Pittsburg, Pa.
Thayer School of C. E., Hanover, New Hampshire.
The Locomotive, Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.
The Mining Bulletin, Pennsylvania State College, State College, Pa.
The Technic, Ann Arbor, Mich.
The Technical Society of the Pacific Coast, Room 56 Academy of Sciences, San Francisco, Cal.
Thompson, B., Box 430, Chattanooga, Tenn.
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Western Railway Club, "The Rookery," Chicago, Ill.
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Chemiker Zeitüng.
Dinglers Polytechnisches Journal.
Electrical Engineer.
Engineering Magazine.
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London Journal of Gas Lighting.
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Scientific American.
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Zeitschrift für Analytische Chemie.